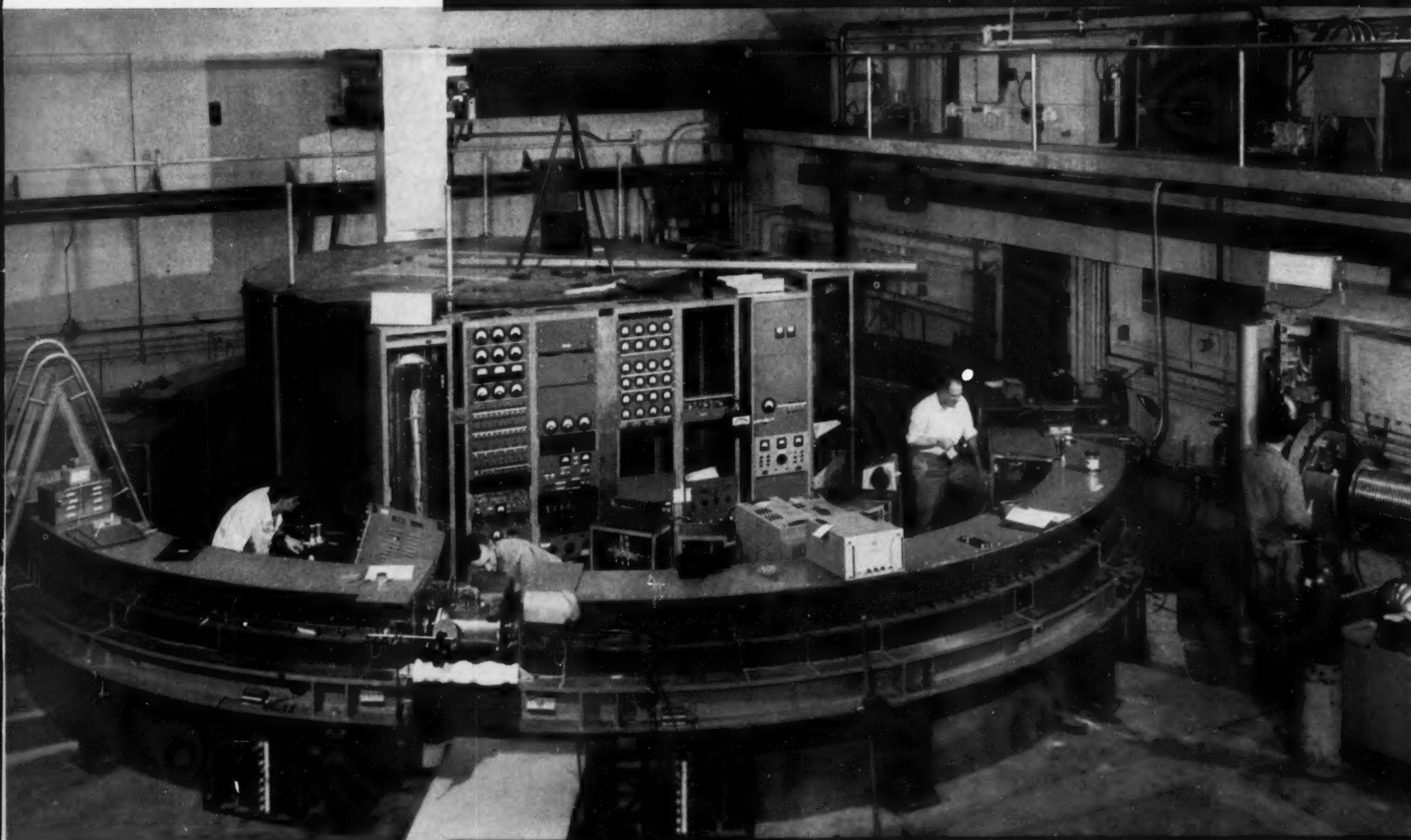
COLLEGE OF ENGINEERING CORNELL UNIVERSITY

the Cornell engineer



MAY, 1955
VOL. 20, NO. 3
25 CENTS

EDITORIAL

"Volume 20 Number 8" marks the final publishing act of the Cornell Engineer for the school year of 1954-55. During the months soon to follow, major plans will take shape in preparation for next year's series, which we believe you will find interesting and appealing.

In addition to thanking our readers for the many useful critical remarks we have received throughout the past year, the staff wishes to present informally the following specific comments on "Reader Communication". We hope you will make serious consideration of these comments.

First:

Beginning with the October issue we expect to maintain a "Letters to the Editor" section, in which each month two or three of our readers' letters will be published for the hopeful purpose of stimulating criticism of the material presented in our feature article (and of the feature articles themselves), as well as in other divisions of the magazine. We invite you to help us make this a useful addition.

Second:

Occasionally (but not frequently) we receive correspondence from readers who suggest specific topics for our editorial board to consider in choice of articles. The subjects so suggested often prove unusually interesting.

Furthermore, many of our readers are in a position to recognize or know about certain subjects important or interesting to others, while they themselves very often lack the time necessary to either write the articles or to locate all the facts. It is of course our business to have the time, and the facilities, to do both. Therefore we invite an increased frequency of suggestions of this kind.

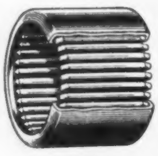
Third:

While many of our articles are written by the students on our staff, articles by others are often included in the Engineer. The "others" are alumni, students not on the staff (two such articles in this issue), and faculty members.

The opportunity is available to these people to volunteer their services as writers, at any time! Open-minded as we are, we will accept suitably prepared articles on almost any subject. The stipulation is that the subject be in some way related to science or engineering. And be it recognized that today, even politics is (and religion is, or should be) related to these subjects. "If you know something useful, write it down."

We suggest that in preparation for the writing of the article you communicate with us, so as to obtain more precise information about length, illustrations, etc., thus avoiding unnecessary "mis-guesses".

The Torrington Needle Bearing ... designed for easy, effective lubrication



One major advantage inherent in Needle Bearing design is the ease with which the bearing can be lubricated.

The full complement of small diameter rollers continuously carries a thin film of lubricant to all contact surfaces. The turned-in lips of the outer shell retain the lubricant and effectively seal out foreign matter.

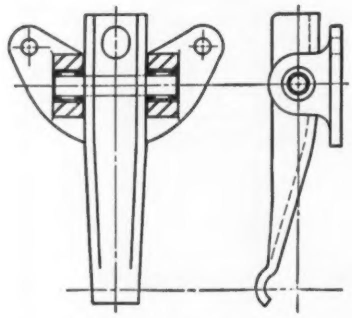
Methods of Lubrication

When Needle Bearings are shipped, they are normally protected with a high-grade slushing compound which has lubricating value at ordinary temperatures. This compound is left in the bearings in most instances. Needle Bearings in many applications run for long periods of time without further attention to original lubrication.

There are several methods of providing additional lubricant to Needle Bearings, as illustrated and described below.

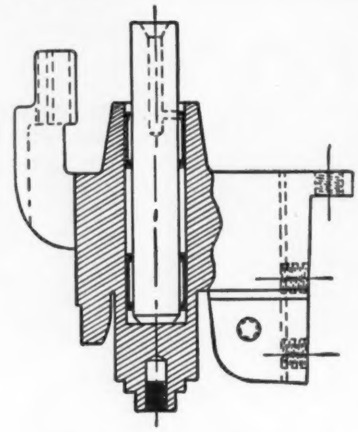
PERMANENT LUBRICATION

For low speed and light load applications, as in the fingers of the automobile clutch illustrated, the Needle Bearings are packed with grease before assembly. No additional lubrication is needed.



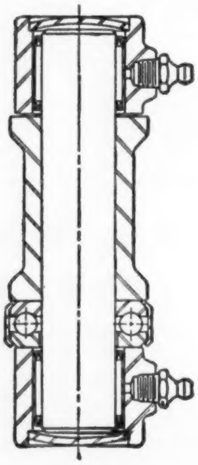
THROUGH THE SHAFT

If it is necessary to lubricate through the shaft, a hole is drilled along the shaft axis, with a cross hole leading under the lips of the Needle Bearing. This hole is located under the lip of the bearing rather than in the roller contact area. Textile machine spindle swing bracket below illustrates this method.



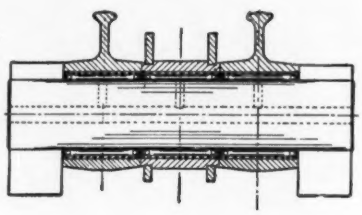
THROUGH THE HOUSING

When lubricant is to be delivered through the housing, an oil hole is furnished in the middle of the outer shell. In automobile king pin below, Needle Bearings are lubricated with Alemite fittings through the oil hole. This oil hole in the outer shell should be outside the load area.



CIRCULATING OIL SYSTEM

For high speeds and heavy loads, a circulating oil system is preferred as it aids in carrying away heat as well as in providing a continuous supply of lubricant to the bearing contact surfaces. A typical example of this method is shown in this Needle Bearing application in the valve rocker arm of a large diesel engine shown below.



Selecting A Lubricant

While oil is the best lubricant, it is difficult in many cases to retain it in the bearing housing. In general, a soda base grease is used in the absence of moisture, and a lime base grease when moisture is present. It is usually advisable to consult a grease manufacturer regarding a particular application.

These features make the Torrington Needle Bearing Unique

- low coefficient of starting and running friction
- full complement of rollers
- unequalled radial load capacity
- low unit cost
- long service life
- compactness and light weight
- runs directly on hardened shafts
- permits use of larger and stiffer shafts

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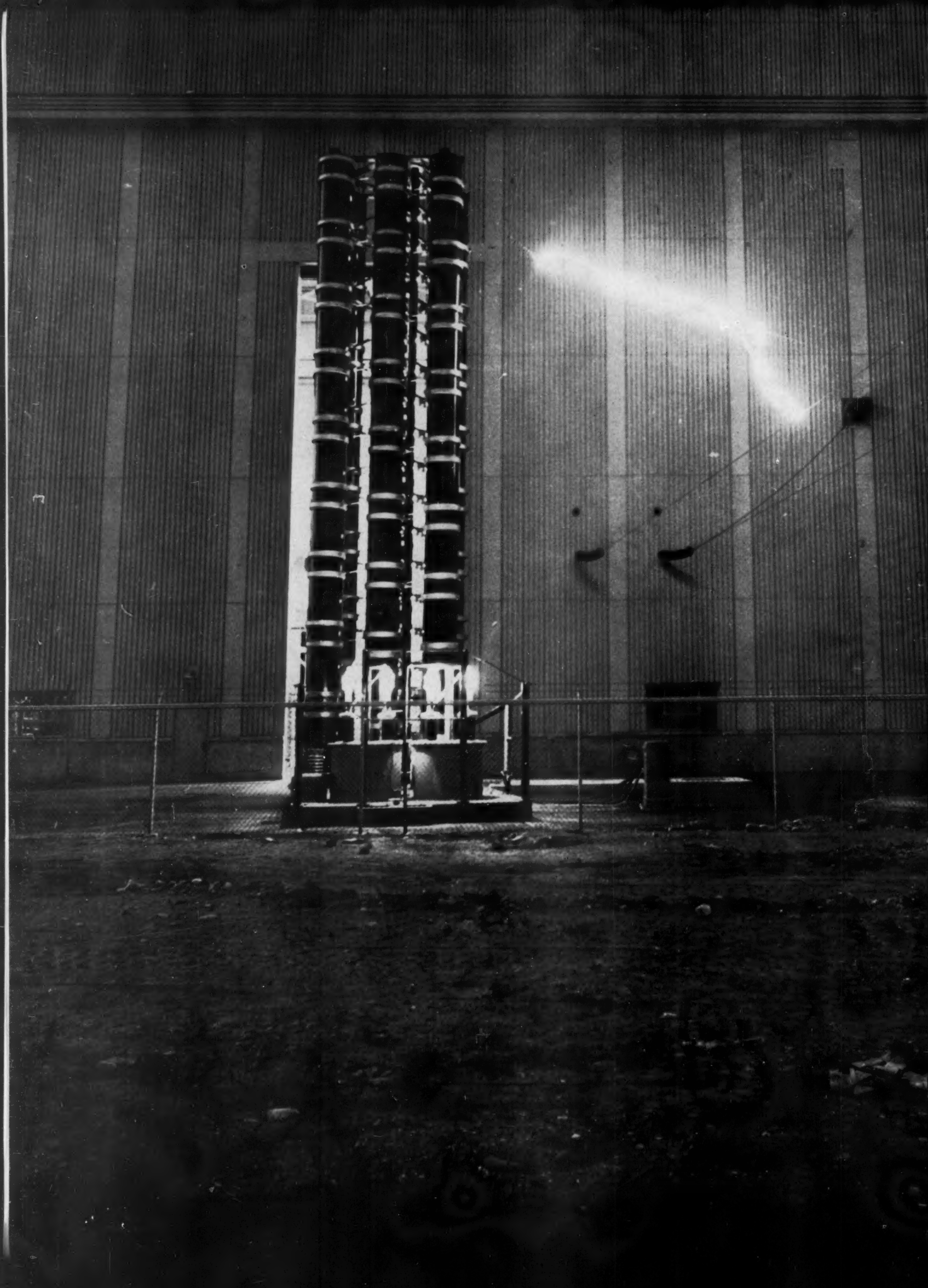


The Nature of Lightning

by LEON HALL, EE '55

(Photographs from General Electric Corporation)

The scene of Fig. 1 is one which is re-enacted a great deal more often than we probably realize. During the months of July and August, when thunderstorms occur most often, the United States will be struck by lightning three times every second. And for the entire earth, the rate is about 100 strokes per second.

Lightning, although it gives us some spectacular displays, is an unwelcome phenomenon in most quarters; it is the fourth most frequent cause of fires and does over nine million dollars worth of property damage annually. This last figure does not include the costly effect lightning can have on electric power systems; however, it is this facet of its behavior which has inspired practically all of the extensive research into its source and nature.

The interest that power system operators have in this field lies in the fact that lightning is potentially a major cause of interruptions in service.. The job of a power system is to provide a continuous flow of power to its connected loads; interruptions are always inconvenient and can be very costly to the consumer and hence to the seller of electric power. If an industrial customer, for instance, was using electricity to run a continuous process such as melting metal, a failure of more than momentary duration would allow the process to freeze, leaving the customer with a mess to clear up before he could restart his operation.

Lightning produces outages on unprotected power systems in two ways—either by damaging equipment or by creating a short circuit. The former can be achieved by huge voltages and currents which will respectively break down insulation and produce mechanical forces large enough to wreck windings in a transformer or a generator.

An impulse generator at G.E.'s High Voltage Laboratory hurls a 7,500,000 volt lightning bolt at a length of a test power transmission line as a part of lightning protection research.

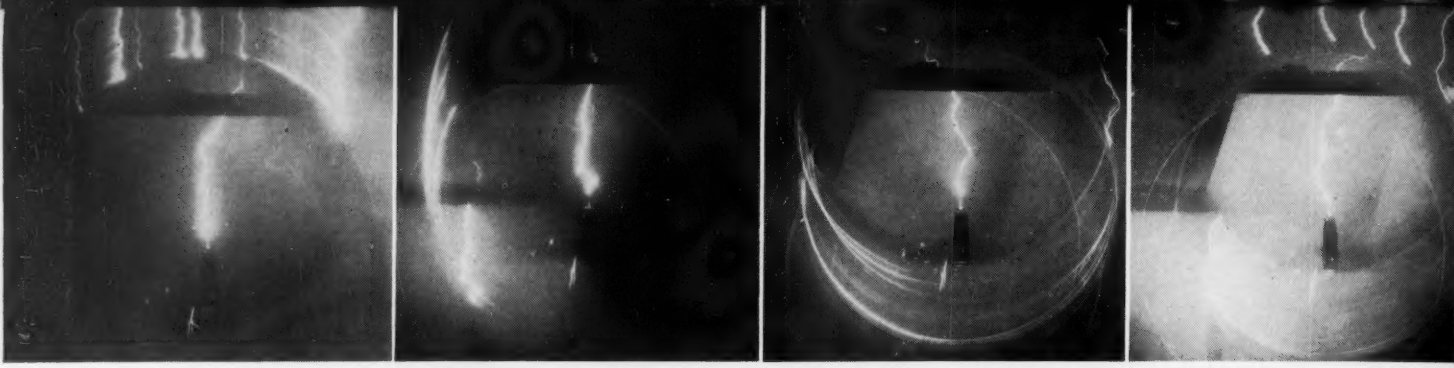
Fig. 1. Natural lightning strokes photographed from G.E. Pittsfield lightning observatory over a period of ten minutes on Aug. 23, 1938.

A short circuit may occur as a phenomenon called flashover, which without destroying certain insulators, makes them ineffective. Overhead transmission lines are suspended from their supporting towers and isolated from ground by strings of porcelain insulators which are made necessary by the fact that the towers are purposely well grounded. Flashover takes place when an abnormally high voltage, which may well appear on the line because of a lightning stroke, is sufficient to break down the air surrounding the insulating string and therefore starts an arc between the line and the grounded tower. An arc is a good conducting path, so it acts as a short circuit which diverts the transmission line current to ground, thus interrupting the flow of power. A similar short or "ground fault" may result from a stroke which strikes a line between two towers and then jumps directly to the earth.

Protective devices have been built which will prevent these events in nearly every case, but to do this engineers have had to gain some understanding of the elemental phenomenon of lightning. Before discussing their discoveries, it is appropriate to mention some of the names and methods of a few men whose work has been most important.

Franklin Pioneers Lightning Study

Certainly the best known contributor to the field was Benjamin Franklin, whose kite experiment in June, 1752, verified his theory that lightning is electric in nature. This pioneering demonstration won well-deserved fame for Franklin in spite of the fact that we know today that he drew from it an incorrect conclusion about the operation of lightning rods and that playing with lightning that way might easily have killed him. He was wrong in thinking that lightning rods prevent strokes by draining the charge from clouds, but, as we shall see later, they do afford some protection. He included a practical essay on this subject in "Poor Richard for 1753," and lightning rods immediately sprang up in a manner probably similar to that of today's television aerials. He was violently opposed in this matter by some New



Stroke No. 13—9:43 P.M. *Stroke No. 14—9:44 P.M.* *Stroke No. 15—9:48½ P.M.* *Stroke No. 16—9:52 P.M.*

Fig. 6. Eight strokes hit Empire State Building in twenty-four minutes.

England clergymen, who thought Franklin impious when he tried to prevent lightning strokes, which they imagined to be hurled from the wrathful hand of God instead of obeying natural laws.

Lightning Strokes Investigated

The number of investigators in this field has grown with the electric industry, and the work has been marked by cooperation between countries and between rival companies. Our knowledge of the mechanism of the lightning stroke is largely due to the work of B. F. J. Schonland from 1933 to 1937 in South Africa, where he obtained some important information from photographs.

The Empire State Building, a popular target for lightning strokes, was used by K. B. McEachron from 1935 to 1942 as a laboratory where more photographs were obtained and interpreted (see Fig. 6). He also connected oscillographs and peak current measuring instruments to the Building's mooring mast to obtain data. At the same time, more natural lightning photographs were being taken for study by J. H. Hagenguth at Pittsfield, Massachusetts.

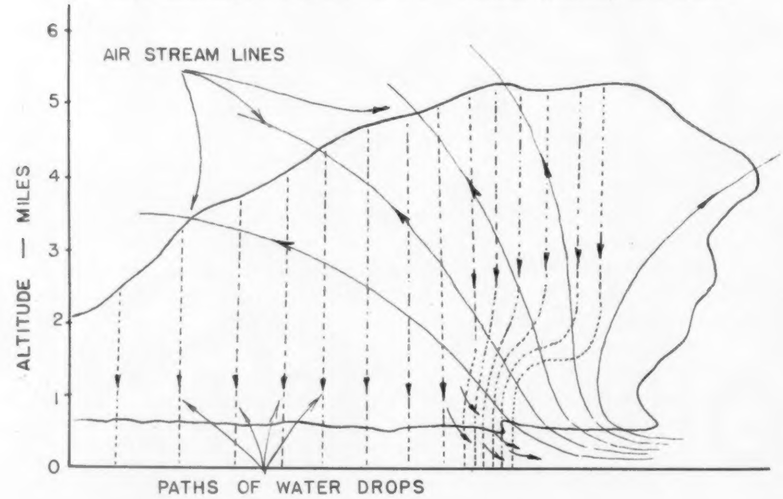
Work on the phenomena occurring on transmission lines and in connection with some protective devices has brought out the names of C. L. Fortescue, L. V. Bewley and F. W. Peek. Their investigations were in some cases made with the aid of artificial lightning created by impulse generators (see Fig. 8) in which lightning currents and voltages are simulated by discharging capacitors. No less important were Bewley's mathematical investigations of traveling current and voltage waves on transmission lines.

Special Instruments Developed

The problem of measuring the large currents and voltages made necessary the development of some new instruments. J. F. Peters invented the klydonograph in 1924; this device has two electrodes with a photographic film between them and a pattern called a Lichtenberg figure, which has a shape and configuration which is a function of the measured voltage, shows up on the film. Current is measured by magnetic links and the surge-crest ammeter. Magnetic links are small lengths of iron which are held in brackets near a conductor where lightning current is expected to flow. The links are originally demagnetized, so a passing current in the conductor will leave residual magnetization in them; the surge-crest ammeter uses this property to determine the peak value of the current.

The photographs by Schonland and his contemporaries were taken with one of the two types of Boys Cameras, the original being introduced by Charles V. Boys in 1900. The high-speed type is shown schematically in Fig. 9. If the film drum is stationary the images of the line AB will be ab and a′b′; but when the drum rotates, the images will be distorted to ac and a′c′. This instrument was used to take the pictures in Fig. 5, and in such pictures the amount of distortion indicates the velocities. The low-speed Boys Camera, which made the photographs in Fig. 6, has two lenses in the same plane with parallel axes; one lens is stationary and the other rotates around it, their axes remaining parallel.

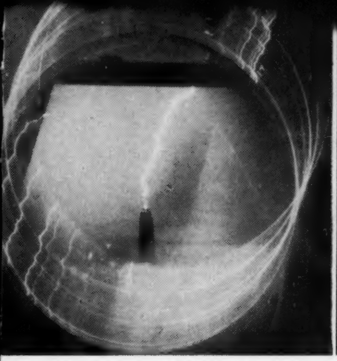
Fig. 2a. Meteorological conditions in a thundercloud according to Simpson.



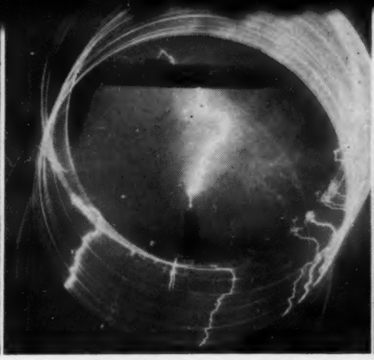
Theories Explain Cloud Charging

The beginning of a lightning flash is usually, of course, in a thunderstorm; the earth's atmosphere experiences an average of 44,000 of these every day. In some manner a cloud becomes electrically charged, the earth beneath it acquiring an equal and opposite charge. The problem here becomes one of meteorology as well as electrostatics.

Although it is evident that the violent air currents usually associated with lightning storms play an essential part in cloud charging, this remains a controversial topic today. A number of theories and variations have been advanced to



Stroke No. 17—9:57 P.M.



Stroke No. 18—9:59 P.M.

Stroke No. 19—10:04 P.M.

Stroke No. 20—10:07 P.M.

explain the mechanism. Three of these are most widely accepted.

Breaking Drop Theory

The "Breaking-Drop Theory" of G. C. Simpson was developed in 1927 after first being suggested in 1909. It depends on the experimentally observed fact that when a water drop breaks apart in air the water "fragments" gain a positive charge while negative ions are released into the air.

Figure 2(a) shows a typical storm cloud with its characteristic upward air stream which is the drop-breaking agent in this theory. A drop of water which is falling freely in air will become unstable and will break apart when it reaches a certain size and "end velocity," and this, says Simpson, is what happens to drops in the upward air stream in the cloud. As has been said, the breaking is accompanied by a separation of charge. The result is shown in Fig. 2(b); the positive water fragments are blown upward, but by recombination with others they become large and begin to fall again. They retain their positive charge when this happens, while negative ions are carried farther up in the cloud by the air current. Thus Simpson arrived at the charge distribution shown, and his measurements of the polarity of the charge on raindrops during storms confirmed his ideas about the lower regions of the cloud.

Influence Theory

Elster and Geitel proposed the "Influence Theory," which makes use in a different way of the rising air currents. These men are concerned with the influence of the normally negative charge of the earth upon raindrops. By induction, the earth's charge results in the bottom of a water drop in a cloud having a positive charge, the top region of the drop being negative.

The rising air stream is said to force small drops to ascend while the larger, heavier ones descend. In this situation the only possible collision between drops consists of the top of the small drops contacting the bottom of the large ones. Therefore, the small drop loses negative charge to the large one, and gains an equal positive charge. As this process continues, then, the bottom of the cloud becomes negative since it is richer in large and more negative drops; and the small positive drops similarly cause a positive charge to appear at the top.

Ionization Theory

In his "Ionization Theory", a third promising idea, C. T. R. Wilson says that each unit volume of air contains a number of positive and negative ions of varying size and mobility, and their number increases in a thundercloud due to the strong electric fields present there.

Wilson, too, considers the polarized drops of water rising or falling through the cloud; as the falling drop, with its positively charged bottom overtakes the ions, it repels the positive ones. But it picks up negative ions and gradually gains a negative charge, as do the lower regions of the cloud. To intensify the effect, this lower negative charge increases the polarization of the drops above it, tending to perpetuate the separation of charge. At the same time the ascending smaller drops also meet positive and negative ions, the negative top of the drop attracting the former and repelling the latter. It thus acquires a positive charge as it drifts to the cloud's upper region and joins the particles accumulating there, aiding in keeping the process going.

A comparison between Wilson's theoretical charged cloud and that of Simpson shows a point of direct conflict—Simpson predicts a region of positive charge at the lower head of the cloud which does not appear in Wilson's picture. In an attempt to clear up this matter Simpson and Scrase used balloons to make sounding of electric fields in thun-

Fig. 2b. Electrical conditions.

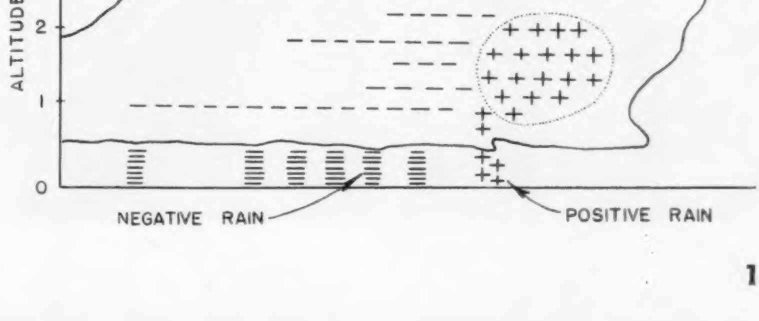


Fig. 3. This lightning stroke to the surface of a lake is accompanied by upward streamers, one of which appears to the left of the base of the stroke.

derclouds; this investigation showed a region of positive charge such as Simpson's. For the remainder of the cloud's bulk the lower areas were found to be negative and the upper areas positive. This agrees fairly well, as do Elster and Geitel, with the observed fact that ninety percent of the lightning strokes to transmission lines are from sources of negative charge.

Ice Crystals Affect Cloud Charging

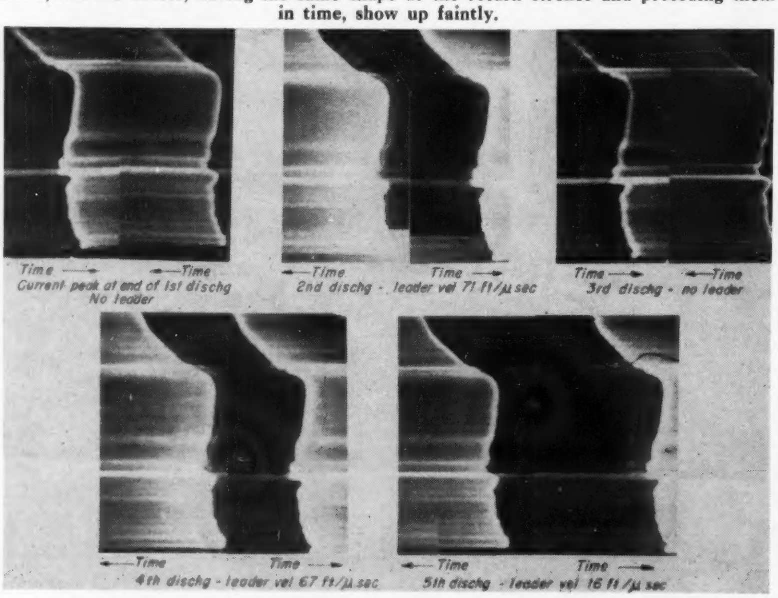
Simpson further discovered that the temperature in the region of separation of the upper positive and the negative cloud charge is generally below —10°C. Ice crystals, not water drops, must be present and be involved in a new charge separation process. He had observed earlier that the collision of blown snow and ice results in a separation of charge between ice particles and air. H. R. Beyers thinks that electrification may occur by interaction of water drops and ice crystals, and E. J. Minser found that the majority of the lightning strokes to an airplane flying in a thundercloud were received in regions where the temperature was within a few degrees of freezing. This temperature condition is not accepted by the theory of W. J. Humphreys that charge separation takes place by breaking drops above the vertical center of the cloud, negative charge being carried by cooling air currents down its sides.

A simplification was used here in that the example cloud of Fig. 2 was given only one charge center, the positive one near its head. The usual thundercloud has many more turbulent air currents, and hence develops more than one charge center. The effect of this situation will be seen later.

Field Intensity Triggers Strokes

The possible cloud charging processes which have been presented here appear to be perpetual — as long as the rapid air currents are present to drive the electrification a charge would seem to continue building up indefinitely to a greater magnitude. Of course this does not happen; the end of the process is the lightning stroke.

Fig. 5. High speed Boys Camera photographs of Stroke No. 26, Aug. 12, 1937, which has five components. Two of the leaders were too dim to appear on the film in two cases, but the others, having the same shape as the return strokes and preceding them in time, show up faintly.



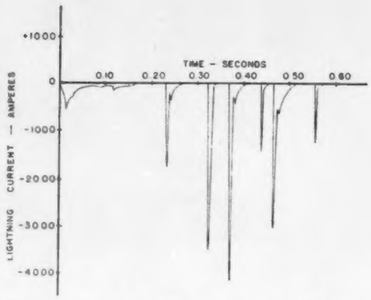


Fig. 4. Reproduction of an oscillogram taken at the Empire State Building of Stroke #13, Aug. 11, 1937. (See also Fig. 6)

When charge builds up in the bottom of a cloud, a charge of opposite sign builds up by induction on the earth beneath the cloud, and an electric field is created between cloud and ground. The intensity of the field is not equal at all altitudes, but is likely to be higher near a charge center in the cloud. When the intensity at some point exceeds the breakdown voltage of air a discharge starts which is similar to flashover, and the lightning stroke has begun.

The lightning stroke mechanism is almost completely understood today, but a few points of vagueness will be noted.

Every lightning bolt consists of at least two stages, assuming that it starts in the cloud; these are a downward leader and a faster upward return stroke. The leader is characterized by low current and brightness, and so it rarely shows up in photographs. The return stroke carries most of the charge, so it is known by heavy currents and the brilliant flashes one sees during thunderstorms.

It is now believed that when previously non-conducting air breaks down to start a stroke, a third stage is involved — two leaders are thought to descend. The first one, which, if it exists, has not had its presence recorded in any way, is called a pilot leader and moves continuously downward. The second one is known to exist and has been photographed. It is known as a stepped leader because its downward motion is in rapid steps which are separated by short pauses, its average velocity being the same of that of the theorized pilot leader.

As long as the charge center can

(Continued on page 52)

Steelmaking Processes

by JOHN M. WALSH, ChemE '59

The United States today produces more iron and steel than all the other countries in the world put together. This is due largely to the fact that the United States has been most singularly blessed in having in ample quantities of excellent quality the three principal ingredients required for steel making. These are iron ore, coking coal, and limestone.

Coal Mining

In modern mining practice the coal is divided into huge blocks by machine cutting and then blasted loose. It is then loaded directly by machine onto a conveyor belt which takes it to the cleaning plant. From here it goes by either railroad cars or boats to the coke ovens located at the steel mills.

The coking process in which the coal is changed into coke is mainly a process of distillation. The coal is put into ovens thirty-five to forty feet long, eight to twelve feet high, and sixteen to twenty inches wide where it is heated from seventeen to nineteen hours at a temperature of 2,000 degrees Fahrenheit. When the volatile gases are driven off, the coke which remains is pushed out of the oven into hot cars. These cars take it red-hot to the quenching station where it is cooled with water. The coke is then ready for use and goes to the blast furnace storage bins where it is stored until needed.

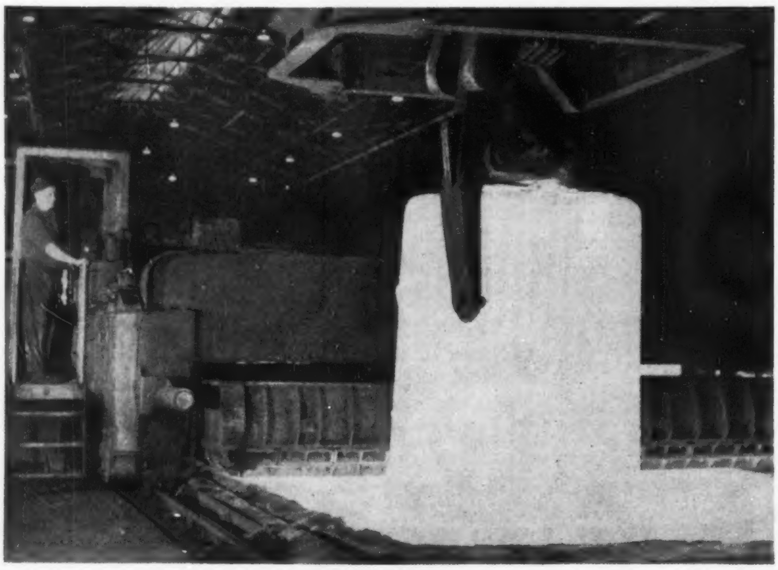
One of the most important operations in the coking process is the recovery of gases driven off during the heating process. In earlier days these gases were allowed to escape into the air. Today these gases furnish fuel for the entire steel plant besides being an important source of several organic and inorganic compounds. These coal chemicals are used to make nylon, fertilizer, drugs, plastics, dyes, explosives and a multitude of other products.

Iron Ores

The major iron ore mines of the United States are of the open pit type. In open pit mining the ore is loaded by huge shovels, which take up to fourteen tons in one bite, into railroad cars or trucks. It is then transported by either rail or water to the stockpiles at the steel mills.

A reheated, white hot ingot, ready for rolling.

—*U. S. Steel*



Limestone

The third important raw material for steel making is limestone, which is used as a flux to remove impurities from the iron. It is either quarried or mined underground with methods similar to those used in coal mining.

Blast Furnace

The modern blast furnace is a tall chimney-like structure ranging in height to one-hundred twenty feet. It is narrow at the top but widens close to the base. The blast furnace runs continuously, shutting down only for necessary repairs. This necessitates charging it with ore, limestone, and coke every few minutes. When a blast furnace is charged, the needed raw materials are carefully measured out and placed in a skip car. The skip car travels to the top of the furnace and dumps in the charge. Approximately three and one-half tons of air, preheated to around 1,200 degrees Fahrenheit, per ton of iron is blown into the furnace through water-cooled openings located radially about the bottom of the furnace and called tuyeres.

This air causes the coke to burn fiercely. The burning coke combines with the oxygen of the air to form carbon monoxide. The highly reducing carbon monoxide rises toward the top of the furnace and removes the bulk of the oxyen from the iron ore in the charge. As the charge falls toward the bottom and the hottest part of the furnace, the iron oxide is reduced to molten iron drops which collect at the bottom of the furnace to form a pool of liquid iron three or four feet deep. At the same time the limestone is purifying the charge by combining with unwanted elements in the ore, mainly silica and alumina. This residue of molten waste forms the slag.

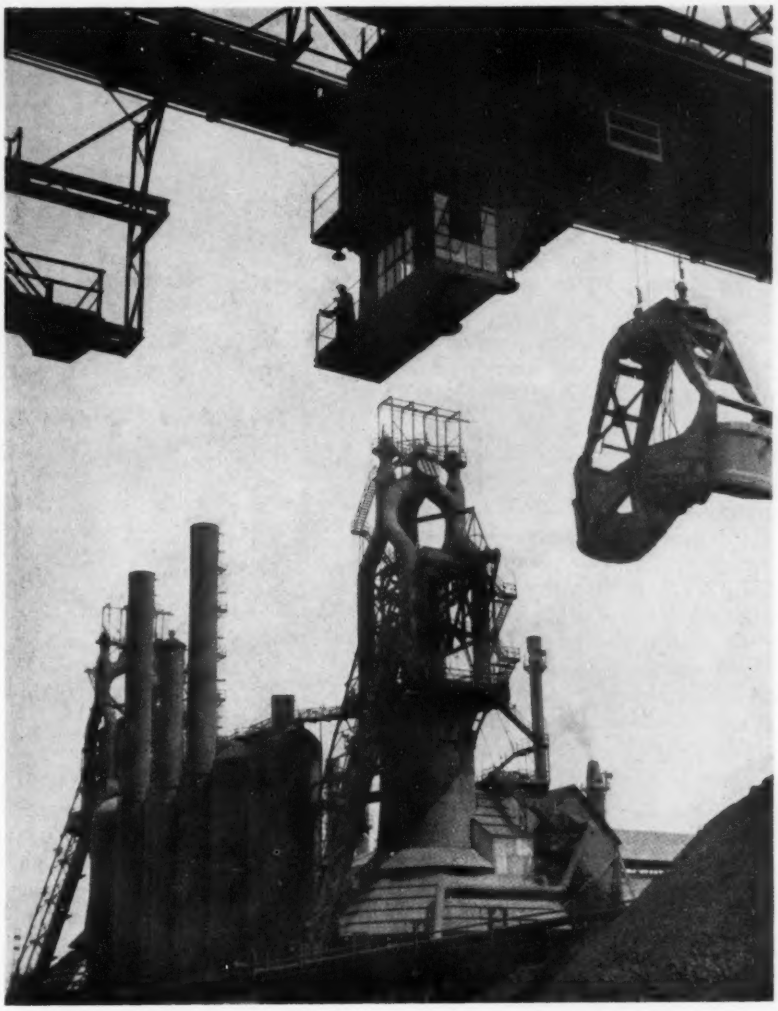
Periodically, the liquid iron and slag are drawn off the bottom of the furnace, separated by gravity, and run through separate troughs into their respective ladles. The molten iron is taken to the steel

making department of the mill or poured into molds to make pig iron for future use. The slag is either wasted or processed for various uses, such as roadbuilding materials, insulating materials, aggregates, etc.

When the iron is cast from the blast furnace, it contains impurities such as silicon, phosphorus, sulfur, and as much as four per cent carbon. A large part of these impurities must be removed. The two principal methods in use today are the Bessemer and open hearth processes.

Bessemer Process

The periodic glow that appears over some steel plants is caused by the working of the Bessemer converter. In the Bessemer process molten iron is poured into the cylindrical shaped converter while it is lying on its side. A blast of air is turned into the vessel through tuyeres which form its bottom; at the same time the vessel is turned upright. The oxygen in the air unites with the silicon, manganese, phosphorus, and carbon in the liquid iron in this sequence. These impurities either go off in the form of a gas or rise to the top as a slag. After twelve to fifteen minutes, when the air has burned out all the impurities, elements are added to the molten metal to give it the required composition. It is then poured into a ladle and in turn teemed into ingots.



A modern blast furnace, where initial steel-making operations begin by smelting iron ore into molten iron.

—*U. S. Steel*

Open Hearth Process

However, by far, the major portion of today's steel is made by the open hearth process. The open hearth is a long rectangular brick structure which has a large dish-shaped compartment inside for holding the molten metal. This compartment is partially charged with limestone, iron ore, and steel scrap. At each end of the open hearth is a burner supplying coke oven gas, natural gas, tar or fuel oil to supply the heat. The air for burning this fuel is preheated in checkers and then entered through the burners. This fuel and preheated air mixture, when ignited, causes extremely high temperatures. After about two hours, the steel scrap is melted, and an amount of molten pig iron approximately equal in weight to the scrap charge is added to the furnace. The oxygen in the ore combines with and removes the carbon, silicon, manganese, and phosphorus. The lime combines with these oxidized impurities and the silica in the ore to form the slag. After eight to twelve hours, the open hearth is tapped into a ladle, additions are made and the steel is teemed into ingots.

Electric Furnace

Although the chemical composition of the steel made by the electric furnace can be controlled more exactly, the method is more expensive than the open hearth and Bessemer methods. For this reason only highest quality steels—stainless steel, heat resistant steel, and tool steels—are made in the electric furnace. The electric furnace has a huge dome-shaped roof with three carbon electrodes protruding into the inside. The carbon electrodes carry the current used to heat the steel and are each capable of being raised and lowered separately. Generally, the electric furnace is charged with cold materials in a method similar to open hearth charging.

When the electricity is turned on, the terrifically high heat given off by the electrodes melts the raw materials. When the first layer of slag forms on top of the molten metal, it is scraped off with raddles. The rake-shaped raddles are made of wood so they will not change the composition of the steel when they burn. The first slag scraped off contains the impurities phosphorus, manganese, silicon, and carbon. After the first slag is removed, a second slag is formed and is removed. It contains sulfur and other elements. At this point special

metals are added to form alloys. After four to twelve hours, the furnace is tapped into ladles and teemed into ingots.

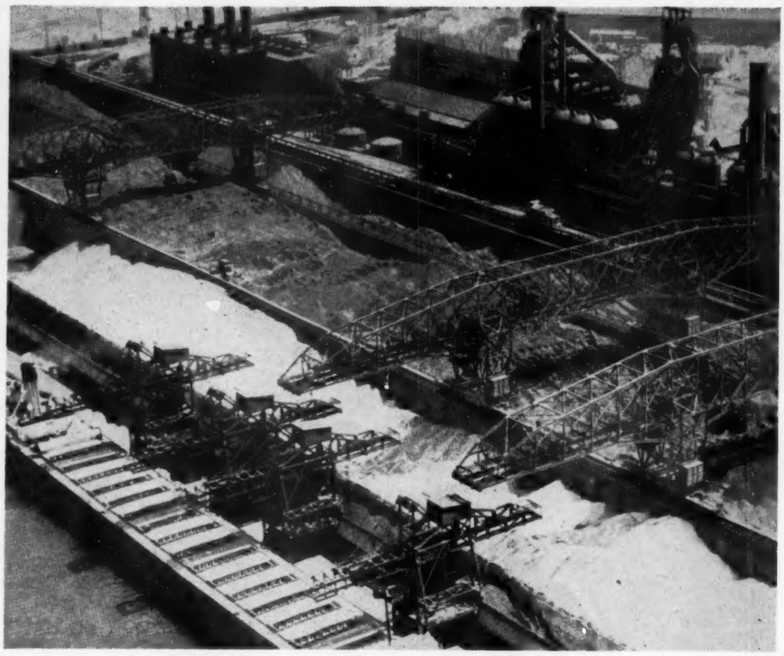
Rolling Mills

The steel ingots are heated uniformly throughout to a temperature of 2200 degrees Fahrenheit in the soaking pits and then moved to the semifinishing mills where the steel is rolled into blooms, billets, and slabs. The major portion of all of these are reheated before rerolling. Blooms and billets are rolled into such finished shapes as rails, structural shapes, rounds, concrete bars, etc. Slabs are rolled primarily into plates or sheet and strip steel of which a large portion are used in the automotive and canning industries. Much of this steel is coated with zinc or tin either electrolytically or by the hot dip method. The rounds may be pierced to form seamless tubing or may be rolled down to smaller sizes and then drawn through dies to form wire. Narrow strip may be curled up at the sides to form a pipe by welding the adjacent edges together.

There are two other methods of shaping steel—forging and casting. In forging the steel is pressed into the desired shape. This is the method used for making railroad wheels. Casting is forming steel by pouring molten steel into a form and letting the steel harden into the desired shape. Casting is especially important in the manufacture of heavy machinery.

Linz-Donawitz Process

The newly developed Linz-Donawitz process appears to have great possibilities. In this process oxygen is blown under very carefully regulated conditions through a water-cooled tube onto the top of a bath of molten pig iron. The vessel used is very much like the Bessemer converter except it has a closed bottom. The oxygen combines with the impurities in the molten pig iron oxidizing them either to a gas or to a slag. The advantage of the process is that no nitrogen is introduced into the steel as in the Bessemer process. One of the disadvantages is the heavy brown fumes caused by the volatilization of the iron and the corresponding heavy iron loss.



Ore boat unloading at dock beside raw materials storage yard.

—U. S. Steel

Direct Casting

There have been many attempts over the years to cast steel directly from pouring ladles into continuous shapes such as slabs, blooms, and billets, thus eliminating the primary rolling mills. This is being accomplished today at several places both in Europe and in this country. Molten steel is poured from the ladle into a tundish, a type of funnel, and then dropped into a vertical water-cooled copper mold where it is shaped into a slab or billet. The mold oscillates vertically to keep the solidifying steel from sticking as it drops downward. As the solidifying section comes out of the bottom of the mold, the steel is given a quick final processing in three steps: tubes spray a coolant to lower the temperature of the red-hot steel; pinch rolls press against the steel and give it a downward tug; a moving torch moves across the steel to cut it into sections. The individual slabs drop into a metal basket that turns them down onto an outward bound conveyor.

Taconites

The great Mesabi Range is fast becoming depleted. To replace this source of iron ore the steel industry is turning to lower grade iron bearing materials called taconites. These are iron oxides mixed with silica in very small grain sizes. These taconites must be beneficiated to a much higher iron content and a much lower silica content before smelting. The present primary concentration process is to crush these iron bearing rocks in huge gyratory crushers followed by cone crushers to a size where they can be handled in a rod mill. This mill crushes them to a point where they can be handled by a ball mill which further crushes them to approximately 200 mesh. The iron bearing materials are then separated from the tailings either by magnetic or flotation processes or combinations of these two. The resultant concentrates contain approximately 60% Fe but being of the magnitude of 200 mesh they are entirely too fine to be smelted in a blast furnace. They must be agglomerated. There are three major agglomerating processes undergoing elaborate experimentation at the present.

Nodulizing

One is nodulizing. Here the concentrates are fed into a 350 foot rotary kiln, rolled up and fused into metallic balls approximately one half inch in diameter.

Sintering

In sintering the concentrates are

(Continued on page 52)

CYCLONITE

Known to the Military as "RDX", this compound has explosive properties of great interest to organic chemists

by C. V. CHESTER, Chem E '56

Ever since some person or persons unknown discovered the art of producing black powder, men have searched for better mixtures and compounds which could rapidly release quantities of stored chemical energy, under the proper stimuli. The Nineteenth Century was most notable for the successes in this quest—virtually every explosive compound known today was first synthesized after 1840 and before 1900.

Is There a "Best" Explosive?

The question is often asked, "What is the 'best' explosive?" The response to this is, "What does one mean by 'best'?" A good explosive should be powerful, cheap, physically and chemically stable, non-toxic, insensitive enough to use, and yet easily initiated. Perhaps the most powerful explosive is a stoichiometrically balanced mixture of tetranitromethane and toluene. But this stuff is dangerously sensitive to initiation, and also is rather volatile. Ammonium nitrate is one of the cheapest explosives known, but it is weak, hard to detonate, and readily takes up moisture from the air to become unexplodable. Nitroglycerin is powerful and cheap, but is too sensitive and chemically unstable, even in dynamite, for many applications. Trinitrotoluene, or TNT, has very nearly ideal chemical and physical properties, but is not as powerful or economical as one might like.

The explosive compound generally conceded to have the "best" combination of desirable properties was not well known, and, in fact, did not see other than experimental use prior to the second World War. But it was first synthesized in the last century.

In 1899 a German chemist by the name of Henning patented a white insoluble product of the nitration of the nitrate of hexamethylene tetramine. Ignorant of its explosive nature, he thought his compound might have medicinal properties. It is ironic that, to date, the largest-scale use of Henning's "medicine" has been to shatter cities of his native Germany, in British and American blockbusters.

Hertz, working in the United States, discovered and patented, in 1920, the use of the compound as an explosive. This compound is now known in the United States and Britain as "Cyclonite," from its cyclic structure and powerful blast effect. During the last war, the code name RDX was applied by the British, but this name has come to refer to certain commercial and military mixtures containing the compound. The Germans and Italians used Hexogen and T-4, respectively, to denote the explosive.

Physically, cyclonite in the pure state is usually a rather fine white powder, which under the microscope appears as colorless orthorhombic crystals. The crystals have a specific gravity of 1.816, melt at 204.1° C. and dissolve readily in acetone, warm concentrated nitric acid, hot aniline, and phenol. They are almost insoluble in water and a number of organic solvents.

What is of interest about this material is that, pound for pound, it is the most powerful explosive of the chemical compounds known to man. Its blast effect is one and one-half times that of TNT. It is about ten percent more powerful in this respect than pure nitroglycerin. It is exceeded in *brisance*, that is, sharpness or shattering ability, by only dinitroglycol and erithritol tetranitrate, and then only slightly.

Tests Indicate Explosive Qualities

Power of an explosive usually refers to its heaving ability: how much dirt, rock, and rubble can be lifted by a charge. A fairly good, i.e. reproduceable, measure of this quantity may be obtained by observing the momentum given a ballistic pendulum by the detonation of a specified amount of the explosive. Comparison of the powers

Components for the detonation test of an RDX explosive. From top to bottom; a 20 gram, one inch by one inch paper-wrapped cylinder of RDX Composition C-3, an electric detonator, and a 4 inch by 4 inch piece of ¼ inch 1020 steel plate.

of explosives in a semi-quantitative manner is usually made from ballistic pendulum data, often using TNT as a standard.

Brisance is usually tested by detonating a small quantity of the explosive in a strong container filled with a carefully sieved quartz sand. The weight of sand crushed such that it will pass the next smaller sieve is a standard measure of this quality.

Sensitivity, or lack thereof, of an explosive is indicated by the height from which a given weight must be dropped to explode a sample on an anvil a given fraction of the trys—often ten percent. On this basis cyclonite has a ten percent success drop height using a two-kilogram weight, of 18 centimeters, as compared with 15 for nitroglycerin and 100 for TNT.

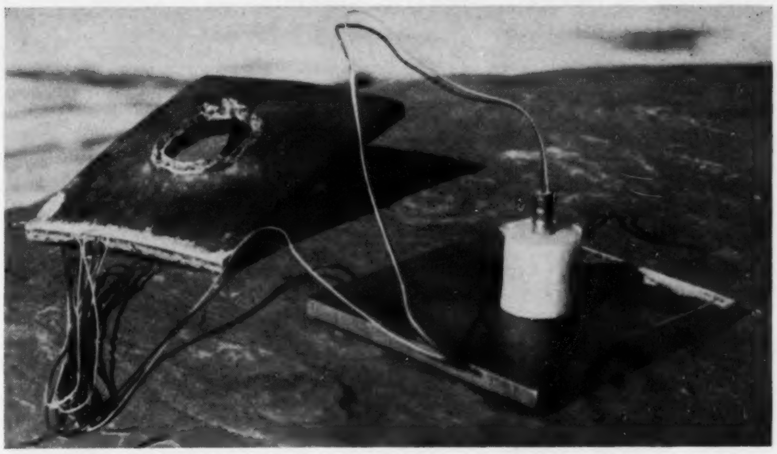
From these figures, pure cyclonite is much too sensitive for military use. This is the case, and pure cyclonite is not used as such. Fortunately the explosive is very easily phlegmatized; that is, made much less sensitive by mixing with it a small amount of some substance such as wax, castor oil, or some resin. The power of the explosive is not appreciably reduced by this process.

The Manufacture of Cyclonite

Chemically, cyclonite is known as cyclo trimethylene trinitnamine, or 1, 3, 5-trinitro hexahydro-s-triazine. (The latter more esoteric name is preferred by organic chemists who like to impress the ignorant engineers.) The essential steps in the preparation are shown in figure 1.

An aqueous solution of formaldehyde and ammonia is evaporated to dryness, and the residue, a crystalline white solid, is urotrapin, or hexamethylene tetramine. This substance become cyclonite when dissolved in a large excess of 98% nitric acid, and the ensuing is solution drowned.

The dependence of the process on formaldehyde and ammonia precluded much interest in cyclonite as a military explosive before 1920. Formaldehyde is made from wood alcohol, or methanol, and prior to this date, the sole source of methanol was the distillation of wood—a rather expensive process. Ammonia, also, at this time was pro-



Test components assembled, and result. The test assembly, shown here on rock, is actually fired on soft sand, by connecting a dry cell to the detonator wires. The fired test plate to the upper left shows the neat hole cut by the explosive. The bottom of the plate is shown. Note how the plate is bent slightly, indicating how sharp, or brisant the explosion was.

cured from natural sources and was not cheap.

However, before and after the First World War, experimental work in France and Germany was going on, aiming at the synthesis of methanol and other organic compounds by the catalyzed reaction of hydrogen and carbon monoxide under pressure. This work culminated in the production of methanol on a commercial scale in 1923 by the Bzdisch Anilin- und Soda- Fabrik. Production of synthetic ammonia from nitrogen and hydrogen was developed at the same time, using an identical process and equipment.

With nitric acid produced from the oxidation of ammonia, it became possible to produce an explosive from no other materials than coke, water, and air. This attracted interest in Europe, which suffered an oil and fat shortage. However, it is a long hard way from the test tube to the pilot plant, and then to commercial production.

British Pioneer Large Scale Production

About 1922, the British, who were the most successful in the large-scale production of the explosive, began investigating the synthesis of cyclonite at Wollwich Arsenal. The original batch method developed by von Hertz was dangerous, for many unstable and sensitive by-products were produced by side reactions. After much painstaking work, interspersed with an occassional rather spectacular reaction, these by-products were identified, and some of their properties determined. A method was developed consisting of continuous nitration followed by a hot dilution, which safely decomposed the unstable products. In this process, hexamine is added continuously to a large excess of 98 percent nitric acid kept at room temperature. The mixture is then diluted with water at 70° to 80° C. precipitating stable grannular cyclonite, which is then purified, phlegmatized, and packed.

In 1933 the process at Woolwich went on stream producing 75 pounds of explosive per hour, without recovering the acid in the dilution. This was the first trouble-free, commercial-scale production of cyclonite in the world.

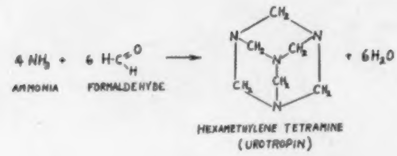
Over 11 tons of nitric acid were consumed in the production of one ton of cyclonite by this process. Of this, approximately 5½ tons can be recovered by absorbtion of the quantities of nitrous fumes evolved in the nitration and dilution. The problems of fume absorbtion and acid concentration on this scale were relatively new to the British Chemical engineers on the project, but they did a very competent job, and by 1939 acid recovery was in operation at Woolwich.

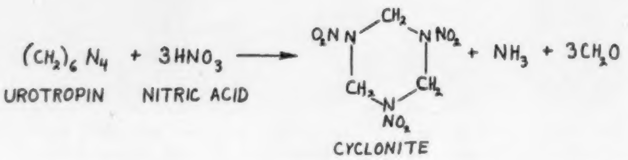
In 1941 a full scale plant near Bridgewater, England, was completed and produced its first RDX. Initial capacity was 90 tons per week, and was later increased to 180.

Process Has Expense Drawback

This process, while producing a

$$\underset{}{(CH_2)_6N_4} + 4HNO_3 + \underset{\text{AMMONIUM NITRATE}}{2NH_4NO_3} + \underset{\text{ACETIC ANHYDRIDE}}{6(CH_3CO)_2O} \rightarrow \underset{\text{CYCLONITE}}{(CH_2)_3(NNO_2)_3} + \underset{\text{ACETIC ACID}}{12CH_3COOH}$$





good grade of explosive, suffers from several disadvantages. The large excess of 98 percent nitric acid necessitated by fume-off and production of water in side reactions, is expensive, and unreacted acid is diluted at the end of the process. This involves reconcentration and purification of relatively huge amounts of nitric acid (by distillation with sulfuric acid) for any sizeable production rate, and requires an elaborate and expensive plant. In addition, and perhaps the major objection to the process, the destructive nitration of one mole of urotropin produces at least three moles of formaldehyde, which is largely oxidized by the nitric acid, and wasted. One mole of ammonia is also released, but this is largely recovered. Now while formaldehyde from synthetic methanol is cheaper than that from natural methanol, it is by no means free. And even if it were completely recovered in the process, one would have to go to all the fuss and bother of putting it back into urotropin molecules.

A New Approach: The Bachmann Synthesis

Two chemists at the University of Michigan, Doctors W. E. Bachmann and John C. Sheehan, tackled this problem. Their approach was this: if somehow more ammonia and nitric acid can be brought into the process as reactants, maybe the nitration equation can be balanced up, producing nothing except cyclonite and water. Eventually the reaction in figure 2 was evolved. The additional ammonia was added as the very cheap nitrate, supplying some of the NO_2 radical and reducing the demand for nitric acid. At the cost of one more mole of nitric acid, and two moles of ammonium nitrate, the theoretical yield of the reaction can be doubled, a very profitable arrangement.

While the reaction looks nice on paper, it has a couple of jokers in it. One is the water produced. This would dilute the reaction mixture, cause side reactions, and cut down the yield. In more conventional nitrations, such as those of benzene, toluene, glycerin, etc., the water produced is removed by having some sulfuric acid present to take it up by hydration. (The sulfuric acid also helps catalyze the reaction, but is not essential for this purpose.) Unfortunately cyclonite is decomposed by sulfuric acid, so this way out of the problem is denied.

By having a large excess of nitric acid present, the bad effects of the water could be attenuated, but aside from bringing back the reconcentration problem, the second difficulty would be encountered: the oxidation of the nascent formaldehyde. Hot concentrated nitric acid is a patent oxidizing agent, and while formaldehyde is more resistant to oxidation than other aldehydes, it cannot long survive these conditions. To circumvent both of these difficulties at once, the ingenious scheme was devised of using acetic anhydride as the reaction medium or solvent. One mole of this chemical will react with one mole of water to form two moles of acetic acid. In addition, this anhydride is not an oxidizing agent.

"Bugs" In the Reaction

After the basic reaction was devised, it was then necessary to get it to work. This involved finding proper temperatures, concentrations of reactants, rate and order of addition of reactants, and other details that plague the chemist. A series of gunks, goos, and spectacular fume-offs were produced until they were determined. It was found, among other things, that it is necessary to add the reactants (HNO_3, NH_4NO_3, and $(CH_2)_6N_4$) in small equimolar quantities to the hot acetic anhydride. The temperature must be maintained above 50° C to decompose a by-product, known later as BSX. The reaction temperature finally arrived at was about 70°C.

In addition, another by-product, HMX (for "High Melting"), was discovered. This compound is very similar to cyclonite, having an eight-membered ring of four nitramine groups and four methylene groups. The name is cyclotetramethylene - tetraintramine. Four isomers of this compound are produced. Only one, the keto isomer, is stable. Removal of the unstable isomers presented additional complications in the purification of the product.

Three-liquid Synthesis Suggested

As an example of laboratory preparation of cyclonite, the following three-liquid synthesis is suggested in a United States patent (U. S. 2,434,879):

A roll of "Primacord." Resembling rope, this is really a plastic and fiber tube filled with a cyconite-type explosive. Rather than burning like conventional fuse, it detonates at about four miles per second. It is used for the almost instantaneous transmission of an explosion from one point to another.

Three solutions are prepared:

(1) 0.24 moles of urotropin in 160 ml. glacial acetic acid.

(2) 0.48 moles dry ammonium nitrate inl. 11 moles of commercial 97% nitric acid.

(3) 1.7 moles of acetic anhydride.

The acetic anhydride is heated to 60° C in a suitable reaction vessel. The nitrate and urotropin solutions are each preheated to 40° C. and added a small proportional quantities, the reaction mixture being well agitated and maintained between 70 and 75°C. After all the reactants have been added, the mixture is allowed to react for 15 or 20 minutes, and then 640 ml. of water at 40° C. is added slowly. The solution is then cooled to 2° C, held there for four hours, and the product filtered off. The yield should be about seventy to eighty percent of theoretical. The product can be purified by recrystallization from acetone or 70%nitric acid, and should be stored under water.

An example of RDX and Primacord being used simultaneously. The shaped charges being strung on the Primacord will be used to perforate an oil well casing. The cord serves to carry the detonation from the top of a carrier to the bottom and initiates the charges as it passes by them.

New Method Poses Operational Problems

To get from the test tube stage to commercial production by the new method, the aid of organic chemists of many colleges and universities was enlisted, including that of Doctor Blomquist of Cornell After more experimentation, a process similar to the one described above, using only liquid feeds, was developed. The process as used in operation by the Tennessee Eastman Company, involved the continuous mixing of the liquid feeds in a large reactor with provisions for agitation and continuous removal of the resulting cyclonite-acetic acid slurry. Prior to 1949, a cyclonite production rate of 360 tons per day had been achieved.

However this process also had its drawbacks. As a result of the milder reaction conditions and more complex reaction mixture, greater quantities of unstable by-products are separated with the cyclonite. To stabilize the product, an elaborate system of recrystallization from acetone must be used.

The big expense is the consumption of acetic anhydride. It cannot be easily made from only acetic acid. Tennessee Eastman produces it from Ketene, an unsaturated compound which can be made from acetone, and acetic acid. Much work has been done on the recovery of acetic acid from the reaction mixture, as one way of reducing the cost of the process.

The problems of production of acetic anhydride and recovery of acetic acid in the Bachmann process are analogous to those of nitric acid production and fume recovery in the nitric acid process. The Bachmann method usually produces a less pure reaction product, but is somewhat easier to control and safer to operate. Opinion as to which is the better process is divided.

RDX Ideal For Military Use

RDX explosives are the joy of ordinance officers; usually having about 1.3 times the power of TNT. At the beginning of World War Two, Britain was short of aircraft. However, three planes loaded with RDX could carry the destructive power of four loaded with TNT. The comfort this gave the RAF bomber squadrons is obvious. Similarly a frogman, or miner and sapper, can carry the equivalent of 80 pounds of TNT by carrying 60 pounds of RDX.

Being powerful, chemically very stable, easily phlegmatized, and solid, cyclonite has the pre-requisites of an almost ideal military explosive. Its only serious drawback is its expense, which is greater than that of TNT. However this is not always a primary consideration with the military. Since an infantryman under fire, and a bomber over enemy territory are about the most expensive freight carriers known, the savings in weight more than compensates for the increased cost of the explosive.

Cyclonite also suffers from the slight disadvantage of a high melting point, melting with decomposition, and hence may not be cast in shells and bombs. It is usually loaded dissolved in molten TNT, or else mixed with some resinous binder and extruded into the desired ammunition components. "Cyclotol" is the name of a melt-loaded mixture of 60 parts cyclonite and 40 parts TNT, used in bombs where great blast and shattering effects are desired. "Torpex" is a similar mixture with the addition of five or ten percent aluminum flake. The aluminum raises the temperature of the explosion, and increases the blast effect.

Cyclonite In Plastic Explosives

The great brisance and power of

(Continued on page 50)

Brain Teasers

Last month we left a prominent member of the engineering faculty, along with his two assistants, perched precariously in the libe tower with only a pulley arrangement and a weight standing between themselves and the angry mob below. To get them out of this situation, let P represent the professor (weighing in at 195 lbs.), B represent the 105 lb. assistant, C represented the 90 lb. associate assistant, and W the 75 lb. weight—soon to be tossed around like crazy. Now, to get the boys out of the tower, put W in one basket and let it go. This exceeds the 15 lb. maximum difference, but weights are pretty durable. Next, put C in the other basket. C goes down, W comes up. Now B goes down and C comes up. Drop the weight out of the tower again, then P goes down and B & W comes up. Drop W again, then C goes down and W comes up, followed by B going down and C coming up. As a final gesture, drop W again, then C goes down and W goes up. All three men having thus been lowered to safety, they can make it to Sibley on their own—to give another prelim another day.

Our second question wanted to know about the legality of a man marrying his widow's sister. To anyone who might have said that such an arrangement would be feasible in most states, we can only answer: "You are dead wrong." A man who has left a widow would be unable to marry anyone, being deceased as he is.

Thirdly, we wanted to know the denominations of two current U.S. coins totaling fifty-five cents—one of which is not a nickle. The answer is that they are a nickle and a fifty cent piece. One is not a nickle, true, but the other is.

To clear up past business, the winner of the March "Brain Teasers" was an astute old dad, an E.P. from the class of 1956, Donald L. Iglehart.

Thus, with many thanks and apologies to all who have written in with variations of correct answers, we bid adieu until October. See you then.

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At Newman Laboratory . . .

The New Electron-Syncrotron

by ARTHUR H. VAUGHAN, EP '57

In the news recently has been the announcement by Prof. Robert R. Wilson, director of the Newman Laboratory of Nuclear Studies, of the successful first test of Cornell's newly completed electron-syncrotron (coverphoto). This machine incorporates a new and highly important development in its mechanism for maintaining electrons in a circular orbit during acceleration. In addition, the electron-syncrotron, after nearly two years of construction, happens to be the most powerful of its kind (it is an *electron* accelerator) in existence at present. At full power, the machine can eject a beam of electrons having energies up to about one and one half billion electron volts.*

Difficulties experienced by the now-antique "cyclotron", due to relativistic effects on the masses of the electrons at velocities close to the velocity of light, require the use of synchotron-type, rather than cyclotron-type, accelerators, when high energies are demanded and light-weight particles, such as electrons, are to be used as "propectiles". The cyclotron depends upon the accelerated particles keeping constant mass in order to stay "in step" with the accelerator oscillator. The syncrotron does not have this defect.

Strong-Focusing Technique

Recent experience with the Brookhaven Cosmotron, supplemented by development concepts of scientists at Cornell and elsewhere, has made it practicable to construct accelerators having far greater capacities at costs much less than heretofore. The new development, being pioneered by Cornell, is to be known as "strong focusing", and makes possible great reduction, in magnet sizes from those in conventional accelerators. The development of machines of this kind represents a tremendously important boost to nuclear studies.

The Cosmotron experience revealed that a beam of charged particles passing through a magnetic field of special shape can be made to hold to a very tight course, i.e., to a circular orbit of small diameter. This is done by alternately focusing and de-focusing the beam of particles. The strong-focusing apparatus consists of a series of lenses, analogous to optical lenes, referred to as "alternating gradient" lenses, to stabilize the electrons in their orbit. The energy for the machine is developed by an RF oscillator, working at 80 megacycles. The requirement of a smaller orbit enables the physicists to produce more energy with a smaller machine. The new device at Cornell is 26 feet in diameter. It's main magnet, weighing 20 tons, is much lighter than the magnets of conventional machines of comparable power.

Because strong-focusing apparatus can be used to accelerate protons as well as electrons (in a proton-syncrotron), it is believed that the principle will enable us to construct accelerators capable of reaching energies on the order of 25 billion e-v.

The Cornell electron-syncrotron, now operating at half power, will be pushed up to full power in stages. Full scale operation is expected some time this summer.

Electrons are injected into the Cornell machine's "doughnut" by a van der Graaff electrostatic generator, at 30 pulses per second and about two million e-v. The electrons are then caused to circle the syncrotron, by means of electromagnetic fields, for a total time of about .012 seconds. During this time they circle their orbit close to 120,000 times, and travel a distance of about 2000 miles.

After acceleration, the electrons possess velocities of about 98 percent the speed of light. Their masses are about 2000 times as great as those of electrons at rest. Their energies are about one billion e-v. After this stage, further increases in energy serve essentially only to increase the masses, rather than the velocities, of the electrons.

Finances

The actual cost of this machine is meaningless, since it contains many parts from Cornell's older, 300 MEV (million e-v), accelerator, now dismantled. To build the usual syncrotron would cost 400 to 500 thousand dollars, which is approximately the total investment represented by both the old and the new Cornell accelerators. Construction of the electron-syncrotron has been the program of a joint agreement of the University, the Atomic Energy Commission, and the Office of Naval Research.

Experimental Program

Facilities of the electron-syncrotron will be available to graduate students at the University, and will aid considerably in speeding up the program of experimental work undertaken by students working on advanced degrees in physics. There is ample space for the preparation of experiments near the machine while other experiments are in progress. The glass "beam tube" may be "tapped" for electrons at any of several locations on the machine's circumference.

Cornell physicists are at liberty to use the machine for any experiments they wish to perform, and are in charge of its operation. No secret or classified work will be done, either on the syncrotron or on the Ithaca campus of the University. The syncrotron will be used to a large extent for investigations into the nature of elementary particles, especially the so-called mesons and associated nuclear forces, and negative electrons, as well as certain other transitory particles. It is possible to cause the syncrotron beam to strike a metallic target to produce high-energy x-rays or gamma rays, also to be used for study. Copies of reports on research involving the electron-syncrotron will be sent to the Office of Naval Research as they go to scientific journals, as a part of the sponsorship agreement. Many of the experiments to be performed are repetitions, or extensions on a higher energy level, of experiments previously performed on the old syncroton, and discoveries of new phenomona are to be anticipated.

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* The "electron-volt", abbr. "e-v", is a unit of energy. One billion e-v 1.18×10^{-10} foot pounds, or 4.45×10^{-14} watt-hours.

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"The objects of this Society are to promote the welfare of the College of Engineering at Cornell University, its graduates, and former students and to establish closer relationship between the college and the alumni."

The Cornell Society of Engineers congratulates you and wishes you the very best of luck, future prosperity, and satisfaction in your chosen profession. The past five years of study have been hard ones for you but at the same time they have been years of important accomplishment. Due to the recent tremendous increase in technological knowledge you have had to learn and become familiar with a great deal more than those who graduated before you, but your five years at Cornell have equipped you well to meet the demands that will be placed upon you. Today a very serious and dangerous shortage of trained engineering and scientific personnel in this country provides you with great opportunities. You are fortunate that your services are in such demand and that you have, with the exception of military service, almost a free choice of the type of work you will do and the location where you will do it. This same shortage which gives you these advantages, however, imposes on you at the same time a tougher job to do in that the future prosperity and security of this nation depends on your doing more than might be considered your fair share of work.

Those of you who are fortunate enough to be able to continue your studies at the graduate level are preparing yourselves to fill very important jobs of a more specialized nature in the next few years. The shortage of specialists is equally severe and the demands for them in both the industrial and the teaching fields is just as great.

The Society hopes that after graduation you will have a continuing interest in your University and its problems and that you will take an active part as a loyal and interested Alumnus in supporting, encouraging, and guiding the work that it does now and will do in the future. We also hope you will take advantage of this Society's interest in you and use it as a means of keeping in contact with your fellow Cornell engineers and the progress of the Engineering College. We hope you will try and interest properly qualified young men to study engineering at Cornell so that we may continue to maintain a strong body of Alumni of whom we all may be proud. We of the Society know we can be of value to you and will be able to help you with your future problems and we will welcome you as new members.

W. M. BACON

ALUMNI ENGINEERS

Leon Buehler, Jr., M.E. '21, Chief Refrigeration Engineer, Creamery Package Manufacturing Company, Chicago, Ill., was installed as President of the American Society of Refrigerating Engineers at the Society's 50th Annual Meeting held at the Hotel Benjamin Franklin, Philadelphia, Pa.

Mr. Buehler is the holder of about 25 patents on refrigeration equipment and processes. He is currently Chairman of the ASRE Membership Relations Committee, and formerly has been Chairman of Chicago Section and of the Program, Standards, General Technical, and Membership Committees. He has been a speaker at many of the Society's national and Section meetings and has contributed numerous technical articles to various magazines. Life membership in the Society was granted him this year.

Carlyle M. Ashley, M.E. '24, Chief Development Engineer, Carrier Corporation, Syracuse, N. Y., was installed as First Vice President of the ASRE.

Mr. Ashley joined the Carrier Corporation in 1924. Now Chairman of the Technical Coordinating Committee, he had some years' experience as Chairman of the Research Committee which is responsible for granting ASRE funds for research projects in refrigeration and air conditioning to educational institutions.

Mr. Ashley was Treasurer in 1953 and has also served as Chairman of the Finance Committee and of the Program Committee. A member since 1937, he was elected a Director at Large in 1948.

Joseph R. Chamberlain, M.E. '28, Chief Engineer, Industrial Products, York Corporation, York, Pa., was installed as Director of the American Society of Refrigerating Engineers.

Mr. Chamberlain has been associated with the York Corporation since he worked as a student engineer in 1928. In the past he has served as Chairman and Vice Chairman of the Standards Committee and has been active in the writing of standards. Mr. Chamberlain is chairman of the American Standards Association's B9 interpretations subcommittee. Co-authorship of a 1941 national meeting paper is also to his credit, and he has written numerous other articles and papers.

J. R. Chamberlain

The appointment of **Theodore C. Ohart B.S. in M.E., '29,** as Manager — Marketing of General Electric Company's Silicone Products Department was announced recently.

Joining General Electric in 1929, Mr. Ohart completed the Company's Advanced Engineering Course. During its three-year curriculum, he executed assignments in engineering and manufacturing at Schenectady, N. Y.

Following assignments in the Schenectady Works laboratory, Mr. Ohart did application engineering work in the Lamp Division at Nela Park, Cleveland, O. He went on active duty with the U. S. Army in 1940, and was discharged in 1945 with the rank of major in the Ordnance Department.

After service, he returned to the G-E Lamp Division as its Buffalo district engineer. His post as Division retail sales manager preceded his present appointment.

William Leigh Cook, West Moreland Depot, N. H., **M.E. '00,** died December 15, 1954. He retired in 1936 after more than thirty-five years with New York Telephone Co. and later with New Jersey Bell Telephone Co. He was a member of Sigma Chi.

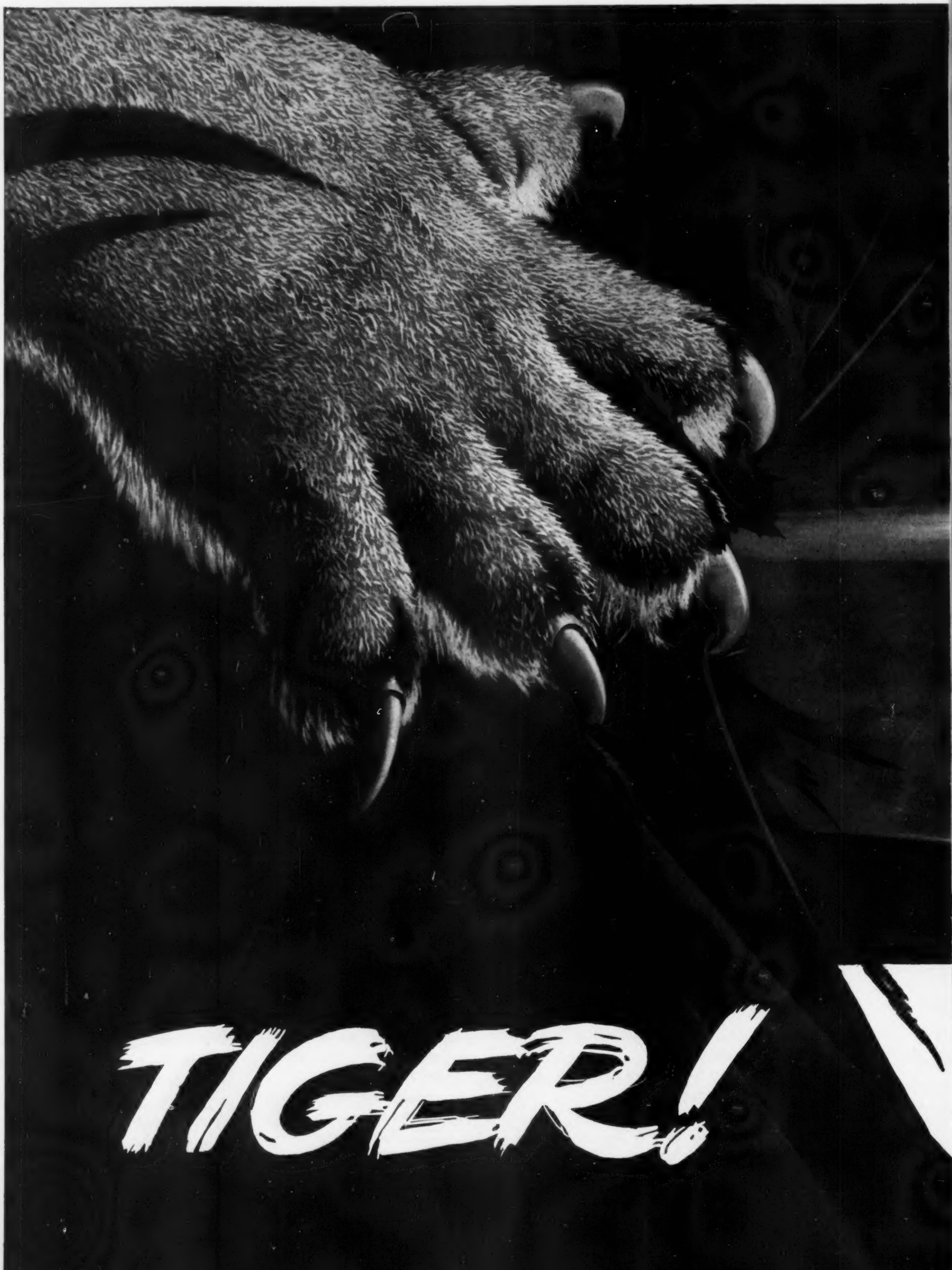
Clarence James Pope, 399 Tremont Place, Orange, N. J., **M.E. '04,** died January 13, 1955. Retired as senior engineer of the New Jersey Public Utilities Commission, he was active on the secondary school committee of the Alumni Association and in the Cornell Club of Essex County. He received the Carnegie Medal for heroism in the Chi Psi fraternity house fire of 1906 in which seven students perished.

Isador Fried ,C.E. '10, 65 Glenview Avenue, Toronto, Canada, died July 22, 1954. A contractor for the last thirty-four years, he had constructed many buildings in Canada, including federal buildings, post offices, and the largest synogogue in Canada. In 1950, he attended the Forty-year Reunion. He left a bequest of $500 to the University.

Kerr Atkinson, M.E. '12, a consulting engineer who lives at 85 Ledgeways, Wellesley Hills, Mass., has been awarded a certificate of merit for his entry in a contest sponsored by The American Society of Mechanical Engineers to find a symbol for its seventy-fifth anniversary celebration in 1955. Atkinson's design, which was judged as best from all the New England States, shows a wheel, square, well pump rig, power plant, and airplane projecting out of radiant arcs and log progress curves. It symbolizes the evolution of technical progress from primitive darkness to the light of today, achieved by the diverse activties of the mechanical engineering profession.

George W. Tall, M.E. '13, 330 Bickley Road, Glenside, Pa., was

(Continued on page 34)

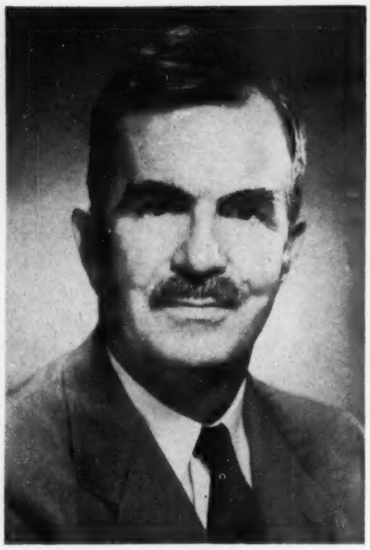

TIGER!

Alumni Engineers

(Continued from page 31)

elected a director of the National Association of Manufacturers at its annual meeting in New York. He represented Scientific Apparatus Makers Association and the Manufacturing Trade Group of the National Industrial Council.

After Tall graduated from Cornell he was with United Gas Improvement Co. in Philadelphia until 1915, when he went with Leeds & Northrup Co., Philadelphia, whom he has been with ever since. In 1944, he became vice-president in charge of sales, and in 1953 was also elected secretary. He is a director of the Scientific Apparatus Makers Association and a member of the executive committee of its Recorder-Controller Section. He is also a member of Industrial Heating Equipment Association, Instrument Society of America, American Society of Metals, Franklin Institute, and the Rotary Club of Philadelphia.



C. M. Ashley

Harold G. Meissner, ME '17 is in the engineering department of Combustion Engineering, Inc., New York City. He lives at 61 Dell Avenue, Mt. Vernon.

Captain Robert E. Bassler, CE '17, CEC, USN (Ret.), is public relations officer for University of Tampa. He retired in 1953 after thirty-six years with the Navy.

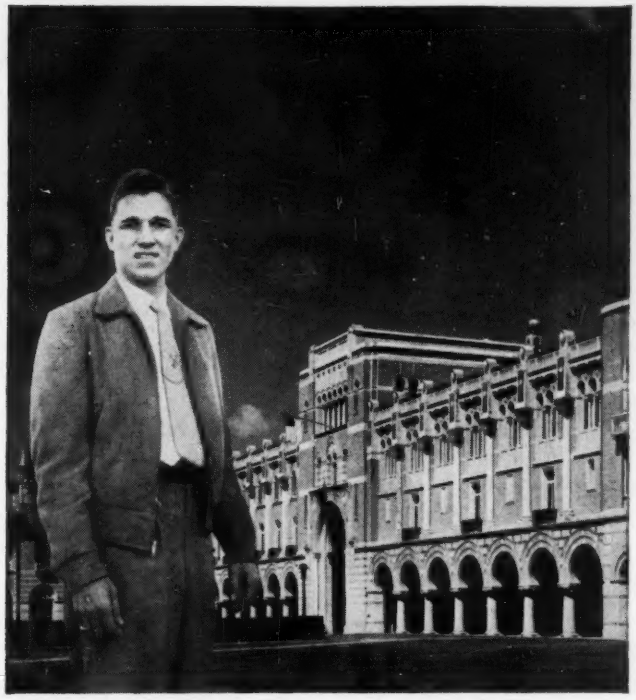
J. Paul Blundon, CE '17, has recently been placed on the retired list of the U.S. Naval Reserve with the rank of Rear Admiral. During World War II he served in the Civil Engineers Corps of the U.S. Navy.

Colonel Philip R. Garges, CE '26, USA (Ret.), is staff engineer for The Citadel, Charleston, S.C. military college. Colonel Garges retired from active duty with the Army Corps of Engineers last year after thirty years of service.

Sanford W. Seidler, EE '46, and Mrs. Seidler (Jean Gordon '49) are living at 134 Haven Avenue, New York 32. Seidler is a senior engineer with W. L. Maxson Corp. of New York.

Cliff Litherland asks:

Would I have varied assignments at Du Pont—or would I specialize technically?



CLIFFORD LITHERLAND received a B.A. degree from Rice Institute last year, and is now working for a B.S. in Chemical Engineering. He is Business Manager of "*The Rice Engineer*," and Vice-President of the fifth-year class at Rice. By asking questions of prospective employers, Cliff is trying to get information that will help him make the best use of his training in the years ahead.

ARTHUR I. MENDOLIA was graduated from Case Institute in June 1941 and started work with the Du Pont Company that same month. In addition to handling challenging assignments at work, he also enjoys some interesting hobbies. Although he makes no claims personally, he's classed as a minor authority on golf and hi-fi music. Mr. Mendolia is Assistant Director of Research for Du Pont's *Electrochemicals Dept.*

Arthur Mendolia answers:

Well, Cliff, I'd say the answer to that question depends largely on your own preferences. In a company the size of Du Pont there are opportunities for growth along either line.

In my own case, I've followed the route of diversification—and I think you'll find that's the general procedure when a fellow is interested in administrative work.

For example, after graduation I started work in the research lab at Du Pont's Niagara Falls plant. That was followed by two years of process improvement work, and a stretch as assistant supervisor over one of the plant areas. Next, I spent a few years in liaison on the design and construction of our first full-scale plant for making nylon intermediates from furfural. Then, I had assignments on "plant start up," and production supervision before I was given my present post. I was made Assistant Director of Research for Du Pont's *Electrochemicals Department* last August.

You see, variety of assignments means contact with new men and with constantly changing problems. That keeps interest alive. It leads to growth, too, because it provides a broad base of experience for future responsibilities.

On the other hand, some fellows prefer to become specialists in a particular field—and Du Pont has many opportunities for that type of professional growth, too. In our research, development and design groups we have experts on distillation, mass transfer, thermodynamics—and most anything else you'd care to mention in the field of engineering. These men are respected throughout the whole company for their technical knowledge.

Whichever route you choose, Cliff—broad or specialized—you'll find that a job well done leads to satisfaction and advancement at Du Pont.

WANT TO KNOW MORE about working with Du Pont? Send for a free copy of "*Chemical Engineers at Du Pont*," a booklet that tells you about pioneering work being done in chemical engineering—in research, process development, production and sales. Write to E. I. du Pont de Nemours & Co. (Inc.), 2521 Nemours Building, Wilmington, Delaware.

DU PONT

REG. U. S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*

WATCH "CAVALCADE OF AMERICA" ON TELEVISION

CORRECTIONS

Last month several printing errors were included in "Telegraph Carrier Systems", by John F. Ahearne.

The indicated expressions should read as follows:

Equation 4, page 7:

$$i_b = K(E_b + uE_c)^2 + a_1 A \sin Vt + a_1 B \sin Ct + a_2 A^2 \sin Vt + 2a_2 AB \sin Vt \sin Ct + a_2 B^2 \sin^2 Ct$$

Equation 7, page 13:

$$i_o = \left(a_1 e_c + a_1 \frac{e_v}{2} + a_2 e_c^2 + a_2 e_c e_v + a_2 \frac{e_v^2}{4}\right) - \left(a_1 e_c - a_1 \frac{e_v}{2} + a_2 e_c^2 - a_2 e_c e_v + a_2 \frac{e_v^2}{4}\right)$$

Equation 10, page 14:

$$I = \frac{A \sin Vt}{2(R_1+R_2)} + \frac{2A}{\pi(R_1+R_2)}\left[\sin Vt \sin Ct + \frac{1}{3}\sin Vt \sin 3Ct + \frac{1}{5}\sin Vt \sin 5Ct + \cdots\right]$$

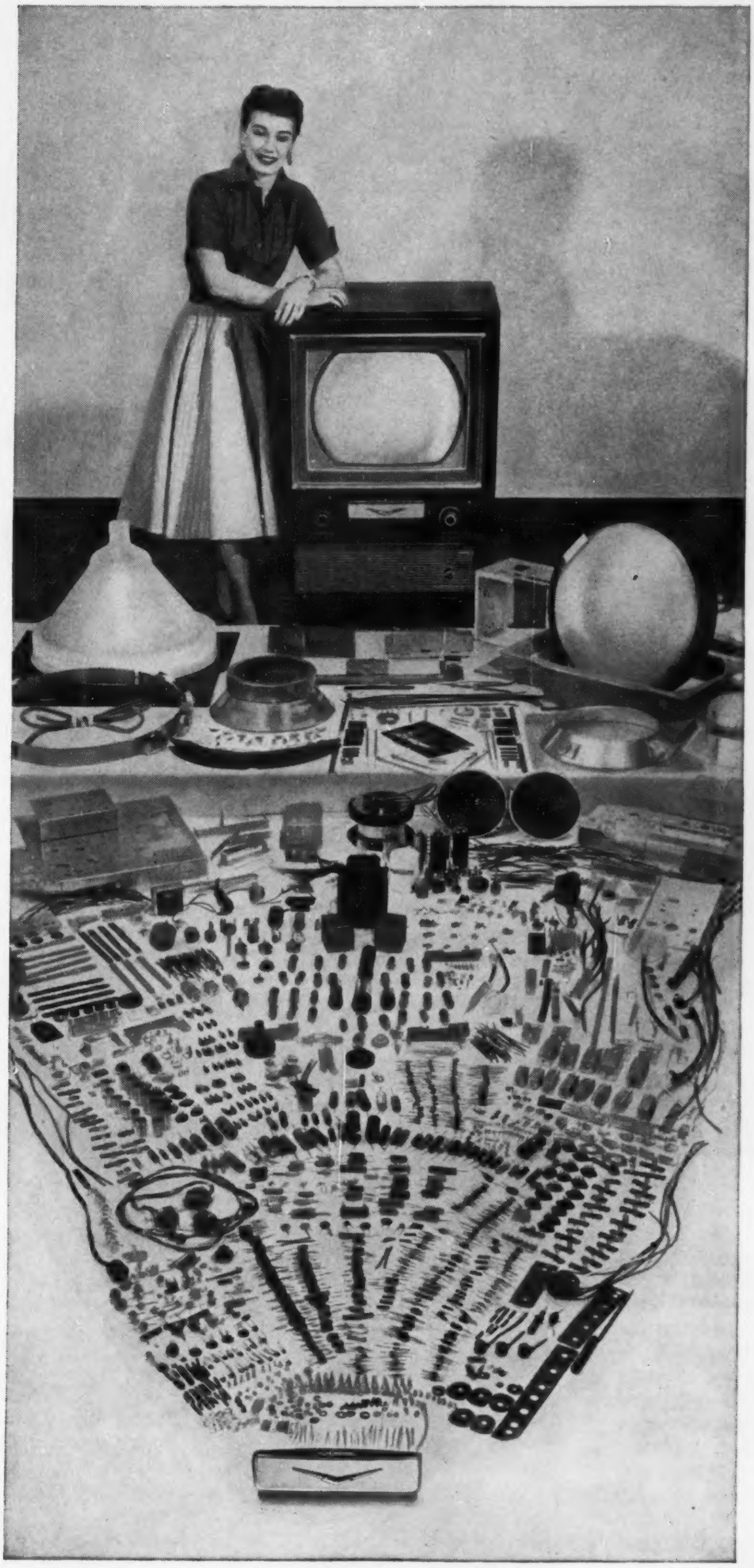
Equation 11, page 14:

$$I = \frac{A \sin Vt}{2(R_1+R_2)} + \frac{A}{\pi(R_1+R_2)}\left[\cos(C-V)t - \cos(C+V)t + \frac{1}{3}\cos(3C-V)t - \frac{1}{3}\cos(3C+V)t + \frac{1}{5}\cos(5C-V)t - \frac{1}{5}\cos(5C+V)t + \cdots\right]$$

Equation 12, page 54:

$$I = \frac{2A}{\pi(R_1+R_2)}\left[\cos(C-V)t - \cos(C+V)t + \frac{1}{3}\cos(3C-V)t - \frac{1}{3}\cos(3C+V)t + \frac{1}{5}\cos(5C-V)t - \frac{1}{5}\cos(5C+V)t + \cdots\right]$$

Credit for all pictures: *The American Telephone and Telegraph Company*, through the courtesy of *Southern New England Telephone Company*.



This picture shows how RCA helps small manufacturers grow

Today the inter-dependence between manufacturer and supplier is stronger than ever in the history of American business. For in the challenging new age of electronics, hundreds upon hundreds of component parts are needed in the manufacture of new products.

For example, the superb new RCA Victor 21-inch color TV set shown here contains 2,070 parts. These are made by 600 different suppliers, most of whom are small businesses.

Indeed, more than three-quarters of all RCA suppliers are small business firms that receive nearly one-half of RCA's purchasing dollars. They, in turn, have their suppliers of raw materials. Thus through a long line of co-operative effort, employment is provided for countless people in many fields—and an entire economy benefits.

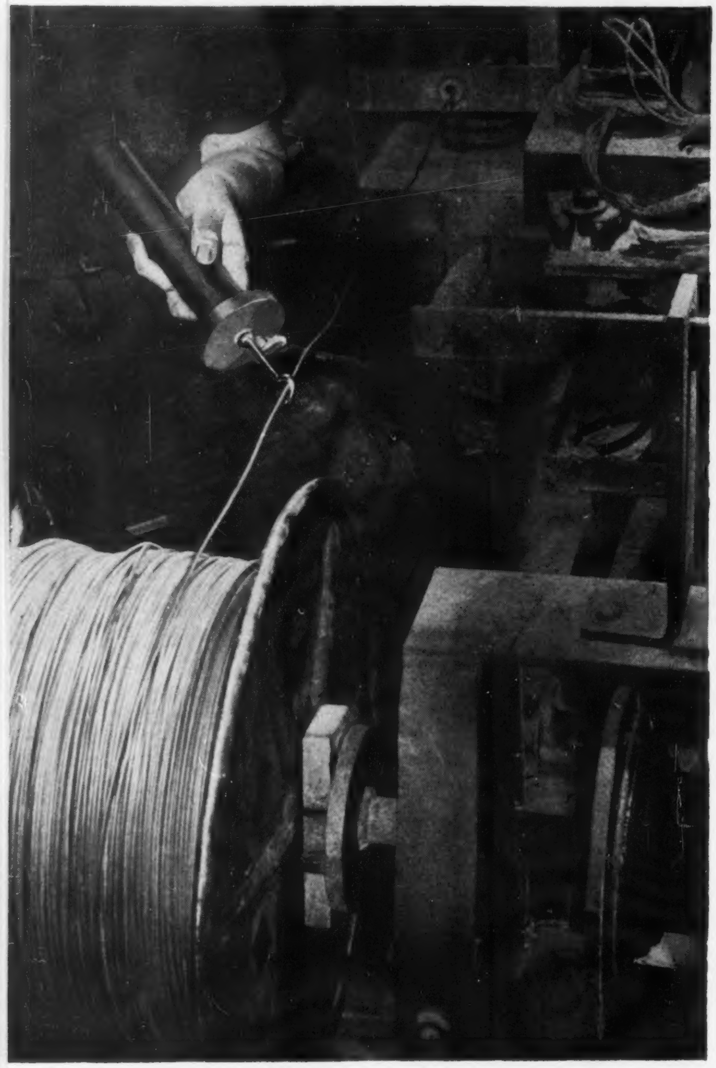
RCA salutes its full roster of 7,500 suppliers, located in 43 states, for their inventiveness and resourcefulness that contribute so much to the quality and performance of its products. With these firms at our side, RCA continues to march forward, creating new and better "Electronics for Living"—electronics that make life easier, safer, happier.

WHERE TO, MR. ENGINEER?

RCA offers careers in research, development, design, and manufacturing for engineers with Bachelor or advanced degrees in E.E., M.E. or Physics. For full information, write to: Mr. Robert Haklisch, Manager, College Relations, Radio Corporation of America, Camden 2, N. J.

RADIO CORPORATION OF AMERICA
ELECTRONICS FOR LIVING

Factory testing of "U.S." electrical wires and cables



CABLE TESTING (Part I)

It has been indicated in a previous section of this series entitled "Cable Specifications" that practically every element of insulated electrical wires and cables may be covered by some specification requirements. Numerous tests are, therefore, necessary to determine the suitability of such cables for the application for which they are designed. These tests may be conducted on (a) the cable elements during manufacture, known as preliminary tests, (b) the completed cables at the factory, final tests, and (c) after installation. Some of the preliminary and final tests at the cable factory such as conductor resistance, high voltage, insulation resistance and corona level are, generally, non-destructive tests and may be conducted on each entire length of cable manufactured. Other tests, such as insulation and sheath thickness, physical, aging, moisture, resistance, ozone resistance, capacity and power factor, short-time dielectric strength and cold bending and long-time dielectric strength tests are made on short samples selected from a lot of cable.

The following is a general description of these tests and their significance as applied to insulated electrical wires and cables. Details of the test equipment required and the specification requirements are not discussed since they are covered by industry publications such as those of the American Society for Testing Materials and the Insulated Power Cable Engineers Association.

FACTORY TESTS

Factory tests are performed for the following purposes: (1) to determine whether the materials of which the cable is made have the required quality; (2) to determine whether the manufacturing processes such as wire drawing, annealing, compound mixing, insulation extrusion and vulcanization have been performed properly; (3) to detect partial or incipient faults that may have accidentally failed to be detected in the tests indicated in (2); and (4) to determine whether the cable meets the customer's specifications.

Tests on Entire Lengths

CONDUCTOR RESISTANCE. Test is made to insure that the conductor has the required average cross-sectional area and, hence, that its resistance does not exceed the allowed maximum.

SPARK TESTING. The entire length of insulated conductor is subjected momentarily to a high potential to detect and permit the repair of imperfections in the insulation that might cause failure on subsequent voltage and insulation resistance tests.

HIGH VOLTAGE TEST. This test is conducted on each entire length of insulated cable to detect potential faults or weak spots in the insulation and to insure that the insulation will withstand the minimum voltage required by the specification for its rated voltage. The magnitude of the test voltage is determined by the type and thickness of the insulation as shown in the following table for 600 volt cables. The time of application is one minute for code grade insulation, and five minutes for the higher grades.

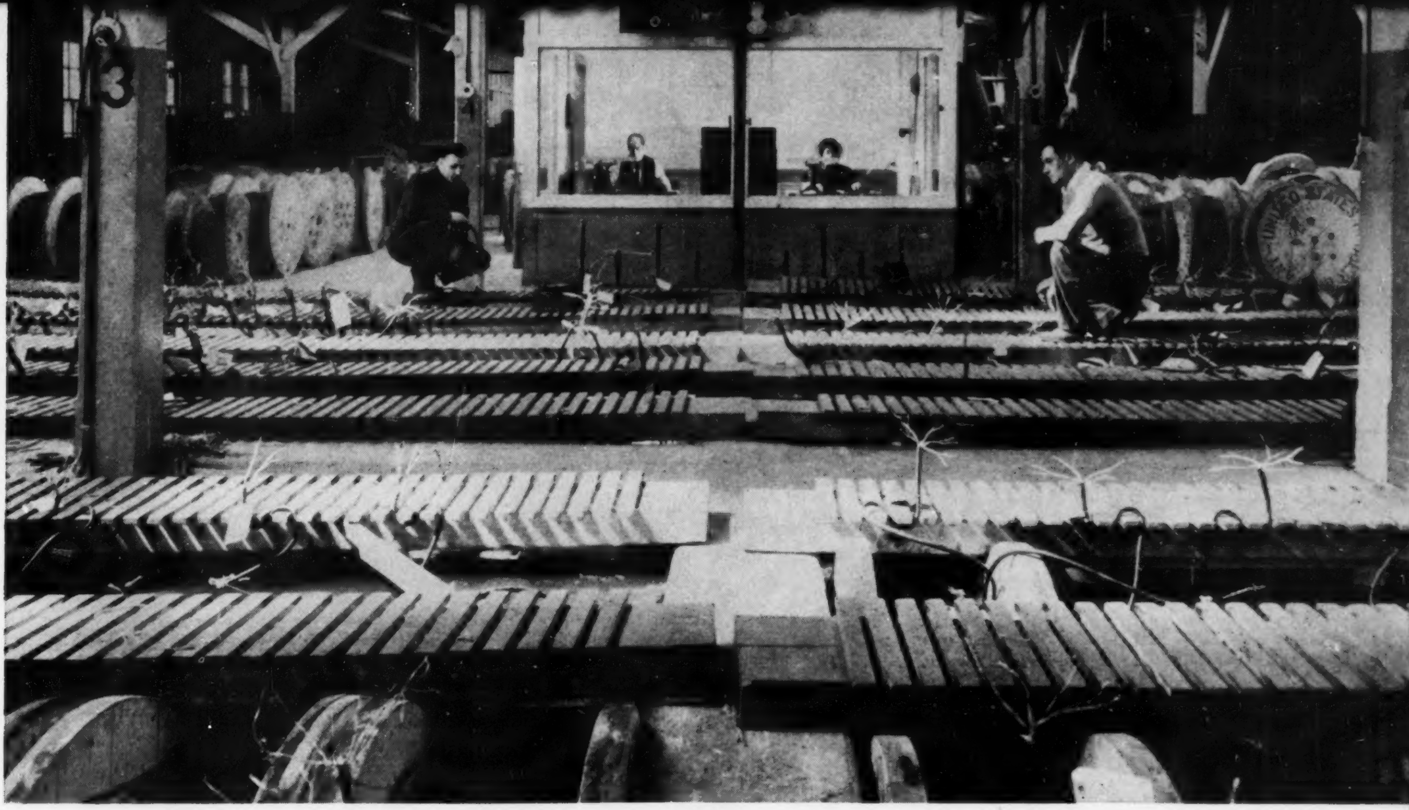
Insulation Thickness and Test Voltage for Rubber Insulations for 600 Volt Service

Conductor Size, Awg or MCM	Insulation Thickness, 64ths Inch	Code Grade	AC Test Voltages Performance and Heat-Resistant	(KV) Ozone-Resistant
14 to 9	3	1.5	3.0	4.5
8	4	1.5	3.5	6.0
7 to 2	4	2.0	3.5	6.0
1 to 4/0	5	2.5	4.0	7.5
225 to 500	6	3.0	5.0	8.5
525 to 1000	7	3.5	6.0	10.0
Over 1000	8	3.5	7.0	11.5

Cables designed for operation at voltages above 5001 are required to withstand a d-c test voltage in addition to the a-c voltage. This d-c voltage is three times the a-c voltage for ozone-resistant insulations and it is usually applied for 15 minutes.

The high voltage test is made by applying the required voltage between the conductor and water in which the cable has been immersed for at least six hours. When metallic coverings are present, the voltage is applied between the conductor and such coverings. Any failures are repaired and the cable again subjected to the voltage.

No. 9 in a series



INSULATION RESISTANCE. The insulation resistance test consists of applying a direct voltage of from 125 to 500 volts, usually from a battery, between the conductor and water in which the cable is immersed, or other ground, and measuring the current that flows through the insulation after an electrification of one minute. A suitable galvanometer is generally used for this measurement. From this current and the applied voltage, the resistance of the insulation is calculated and expressed, usually, as megohms (1 million ohms). This test is conducted after the voltage tests and, hence, serves to indicate whether the insulation failed on that test. Insulation resistance also serves to indicate uniformity in processing, particularly insulation compounding, since a well-processed compound should give reasonably uniform insulation resistance. Most wire and cable specifications contain minimum requirements for insulation resistance so that this test determines whether or not the specification is complied with.

The resistance of insulations is inversely proportional to the temperature, that is, it is lower at high temperatures. It is, therefore, necessary to note the temperature at which the insulation resistance is measured and to apply a correction factor to reduce the resistance to a standard temperature. The insulation resistance varies with the type of insulation, its thickness and the size and length of the conductor. The following formula gives the relation between these factors.

$$\text{Insulation Resistance, Megohms} - 1000 \text{ feet} = K \log_{10} \frac{D}{d}$$

Where, D = Diameter over the insulation, inches
d = Diameter over the conductor, inches
K = A Constant for the insulation used

CORONA OR IONIZATION LEVEL. This test determines the voltage at which ionization or corona develops in a length of cable and is usually made only on cable for operation above 4000 volts. It is made by applying a gradually increasing a-c voltage between the insulated conductor and water or other ground with an oscilloscope in the circuit. Any air entrapped at the surfaces of the insulation or within the insulation will ionize when a sufficiently high voltage is applied resulting in the formation of more active oxygen or ozone. These materials are detrimental to most organic insulations particularly when such insulations are under physical tension, and thus may cause premature failure of the insulation. This ionization is indicated by the appearance of high-frequency oscillations on the charging current trace of the oscilloscope. In actual practice, the voltage at which ionization is extinguished rather than initiated is determined. For long cable life, this extinction voltage should be at least 110 per cent of the rated voltage to ground.

Wire and cable specifications generally require that these tests be made on the completed product. High voltage and insulation resistance tests are usually also made immediately after the insulation has been applied and vulcanized. This is general insurance that cables passing the test will meet the requirements when completed.

RUBBER COMPANY

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Cornell: Pioneer In Dynamo Development

by RICHARD BRANDENBURG EP '58

Phillips Hall, Cornell University's recently constructed electrical engineering building, marks the latest step in the progressing history in electrical engineering on the Cornell Campus. As early as 1883, when an accredited degree in electrical engineering was awarded for the first time in the world at Cornell, the University already had been the scene of many significant pioneering advances in the development of practical equipment and techniques for harnessing electric power in useful service.

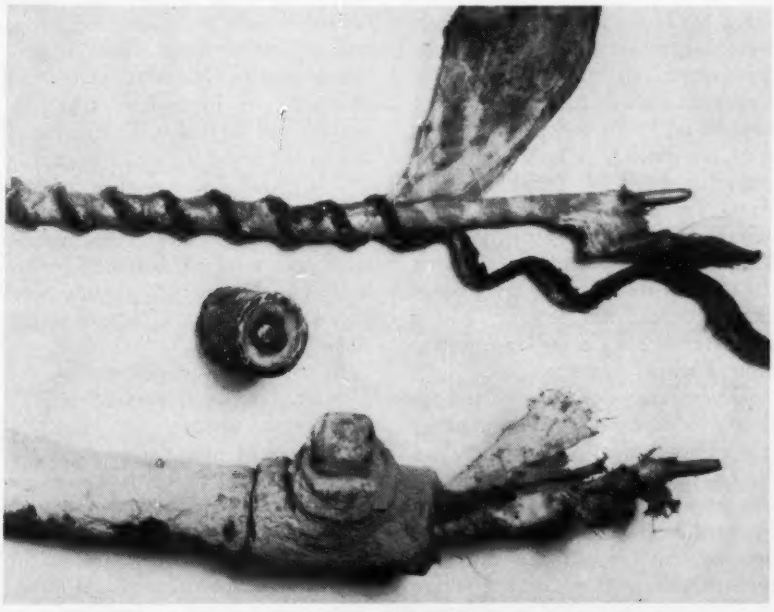
In 1875 Cornell was the birthplace of the first practical dynamo for service use. Ithacans and nearby farmers were amazed as they saw two bright lights on campus shining at night over the valley. These lights were the first practical outdoor lighting system in the Western hemisphere. The dynamo story, the saga of the outdoor lighting system, and the succeeding evolution of electrical engineering study, reflect a tradition of ingenuity and practical inventive skill. As Phillips Hall this spring nears dedication, Cornellians should consider the growth of that tradition underlying the present prominent reputation of the School of Electrical Engineering.

In 1875, the basement of Cornell University's McGraw Hall became the birthplace of the first electric dynamo applicable for extended lighting service. Pioneering in the development of the machine making the Cornell campus the site of the nation's first outdoor electric lightning system were Professor William A. Anthony and George S. Moler. They based their work on the principles set forth in Europe by the Belgian electrician Z. T. Gramme, who in 1869 perfected the method of ring winding for dynamo armatures. The Anthony-Moler machine was specially designed for continued laboratory operation.

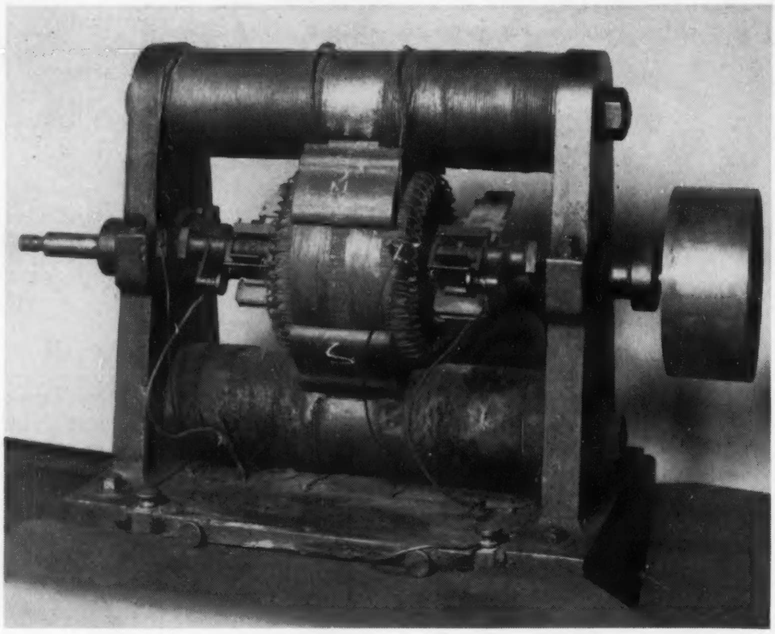
Although other devices for generating electricity had been built prior to the Anthony-Moler machine, they were small experimental types. Simple arc lights had been battery powered, and European house illumination had been achieved with a "magneto machine." Although a working dynamo was constructed in America as early as 1874, the first outdoor lighting and continous service dynamo was introduced on the Cornell campus.

Cornell Professor E. L. Nichols, head of the physics department from 1887 to 1919, noted the revolutionary impact of the Anthony Moler design in a tribute at the time of Professor Anthony's death in 1908: " . . . Thus it came about that inhabitants of remote farms among the hills of central New York saw the arc light shine out night after night long years before the introduction of this means of illumination in Paris, London, New York, Berlin, or any of the other great cities of the world."

The original installation on the campus consisted of lamps located in the tower of McGraw Hall and near Sage Chapel. The two-lamp lighting system shone down from its hill-top location to the amazement of the Ithaca townspeople. However, Ithacans had been introduced to electric lighting by the machine before it was used for outdoor illumination on Campus. After the dynamo was exhibited at the Centennial Exposition in Philadelphia in 1876, it was returned to Cornell for use in arc lighting dem-



The underground cable used in the campus lighting system consisted of gas pipes containing copper wires wrapped with muslin strips. A beef tallow packing was used, contributing to the cable's excellent durability.



The Anthony Moler dyanamo, first practical dynamo for extended service operation.

onstrations in the physics laboratory. When a lighting demonstration took place late in 1878 in the Williams Brothers Machine Shop in downtown Ithaca, the Ithaca Journal reported that the apparatus "caused the place to be crowded with spectators each afternoon as soon as the brilliant flame had been lighted."

By 1879 the dynamo had been pressed into service as a part of the campus lighting system. The generator was run by a water wheel located in Fall Creek Gorge. The machine itself was housed in the gorge in back of Franklin Hall. Wires on poles first carried the current from the gorge to McGraw Hall. However, after objections to the "unsightly wiring" from some of the humanities faculty, Moler and Anthony developed an underground wiring system.

The underground wiring itself reflected significant engineering progress. The cables consisted of gas piping through which copper wire was passed. The wire was insulated by muslin strips and a packing of beef tallow was pumped into the pipes through taps located along their lengths. The cables were so well constructed that sections dug up by workmen in 1939 were found to be in excellent operating condition.

Though the dynamo performed consistently, the lamps themselves were erratic. The late Charles Hull, professor of history at Cornell, recalled the "buzzing and sputtering" of a typical bulb, and observed: "If you had seen it, you never would have called it a single lightbulb. It was an open arc lamp, and its carbons were not copper-cased pencils, but flat plates, so that an arc, instead of traveling around and around to fit irregularities in the wear, jumped backwards and forwards along their edges, from one point to another of their approximate contact. Polychromatic flames resulted, startling to behold. The dynamo was already good . . . but the lamp still needed the rod of correction."

In spite of its imperfections, the pioneer system impressed nearby farmers and townspeople. That Ithacans looked optimistically to the future of outdoor lighting was reflected in the Ithaca Journal's "Town Talk" column early in 1879: "Three such electric lights as the one in McGraw tower would illuminate the village as brilliantly as gas does now. In order to obtain the desired results, the steeples of the churches might be used as electric lamp posts, making them useful as well as ornamental."

The dynamo itself was a practical application of the fundamental ideas first stated by Faraday. Faraday noted that an electromotive force was produced when a metal plate was rotated near a magnet. An entry in Farraday's dairy observed, "So long as the wheel moves electricity is evolved . . . It is not the mere vicinity (to magnets) but motion that evolves the electricity. Must consider this more presently. Could build a machine up this way."

Such a machine was the Anthony-Moler device, having a capacity of 20 amperes at 150 volts. The dynamo continued to operate the campus lights for about ten years until it was replaced by a new Weston dynamo. The original equipment was then used to furnish laboratory current and provide motive power for the physics department machine shop.

The dynamo was used for pur-

Former Professor George S. Moler

poses other than outdoor lighting. During the late 1870's, lecture room lanterns were operated with limelight prepared chemically from oxygen and hydrogen. The limelight method of illumination utilized a cylinder of metal stuffed with ether-soaked cloth. Gas, consisting of a mixture of oxygen and hydrogen, was drawn through the cylinder and lighted. The ignited gas was then directed upon a piece of white lime. The radiation of the lime provided light for slide lanterns. Professors Anthony and Moler devised an appartus using the dynamo to prepare the gases electrolytically. The equipment provided gas for lantern use in various departments on campus for many years. Today the dynamo resides in Rockefeller Hall, where it is preserved for demonstration purposes. In spite of its age, the machine still is in operating condition.

Professor Anthony also laid the foundation for a growing development of Cornell physics when he combined his genius and enthusiasm with meager available demonstration facilities to make the subject more meaningful to Cornell students. During his career, starting at Cornell in 1872, Anthony was instrumental in a number of other important scientific advances. He supported the idea of special courses for students of electricity, resulting in 1883 in a Trustee authorization of a program leading to a degree in electrical engineering. At the time, no other school in Europe or America offered such a course.

Anthony also effected the granting of funds to develop apparatus for the absolute measurement of electricity. A wooden building, completely free from iron was built near the west end of Sibley College. The structure housed a complete set of measuring instruments including a giant tangent galvanometer with coils two feet in diameter.

George S. Moler, who received his Cornell engineering degree in 1875, was in charge of the dynamo laboratory in Franklin Hall when the building housed the chemistry and physics departments. Moler later taught classes in the scientific applications of photography, planning the photography laboratory formerly located on the second floor of Rockefeller Hall, and designing a large part of its distinctive equipment. Moler was one of the first Americans to make x-ray pictures. He was active with Anthony in constructing the tangent galvanometer and other current measuring equipment. In addition, Moler's many inventions included an automatic switch for an early firepump system in Rockefeller Hall.

Thus the work of Cornell Professors Anthony and Moler paved the way for the tradition of electrical engineering progress most recently marked by the completion of the new electrical engineering building, Phillips Hall. The dynamo and the pioneering lighting system were significant advances in the early development of America's electric light and power industry.

to the well too often

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CAST IRON PIPE SERVES FOR CENTURIES

College News

A method of detecting the location of the jet stream, a high velocity "river" of air found far above the earth's surface, is being studied by scientists at the Cornell Aeronautical Laboratory, Inc.

Efficient detection would permit commercial and military airplanes to take greater advantage of the winds up to 200 miles per hour. By using the stream as a tail wind, tremendous savings in flight time and fuel consumption of aircraft could be achieved.

Jet streams are found at altitudes of 25,000 to 40,000 feet. In the northern hemisphere, these invisible winds run roughly west to east, sometimes encircling the earth.

Present detection methods, which include flying into the stream or use of some meteorological techniques, are generally inadequate. An airplane's pilot would not necessarily know he had flown into a jet stream even though he encountered rough air in the process. The pilot would need either to track the ground or be tracked from the ground by radar in order to establish the difference between his airspeed and ground speed. Some navigational position devices are useful but require the airplane to remain in the stream for some time in order to establish true velocity.

The Laboratory's Physics Department, in a contract for the U. S. Navy, has started the project. The first phase of the program calls for the instrumentation of aircraft with equipment to measure electrostatic phenomena, in accordance with the suggestion by other experimenters that the jet stream carries a net electrical charge. The argument was made that an electrostatic field appears at the earth's surface when a jet stream axis is within 150 to 200 miles of the observing station. C.A.L. scientists believe that the existence of electrification in the jet stream is plausible but has not been proven. Flights in or near the stream by an airplane carrying instruments for measuring an electric field should serve to verify or disprove the possible electrification.

Since its "discovery" in the early 1940's, the jet stream has been the subject of concentrated scientific investigation, and, in many circles, controversy. Most of the information gathered thus far relates to its origin and identity. The exact momentary location of the stream is usually not known since a considerable time delay is associated with gathering and analyzing data connected with it.

Wind Tunnel Tests, Erosion Studies

The Cornell Aeronautical Laboratory, of Buffalo, N. Y. has announced that it is currently undertaking the study and testing of two more important engineering problems—the erosion by rain and hail of exterior surfaces of high speed aircraft, and the complete and accurate engineering data on the U. S. Navy's latest supersonic fighter, the Grumman F9F-9 Tiger.

The erosion, or wearing away, of plastic and aluminum structures—a onetime threat to the nation's all-weather defense program—particularly effects the leading edges of the aircraft.

The Laboratory has been one of the leading investigators of this facet of rain erosion for six years and in cooperation with the U. S. Air Force and a number of industrial and research centers has been attempting to obtain information that would lead to an understanding of the nature and mechanism of the erosion process.

The problem was first observed by the Air Force in 1945 when rain striking the leading edge of a radar housing on a high speed plane caused rapid deterioration of the plastic part.

Although progress has been made in the development of elastomeric coatings which greatly reduce erosion, the fundamental mechanism of erosion has not been solved and research will continue. Commercial firms are now providing rubber-like coatings which give 1½ hours erosion resistance at speeds of 500 miles per hour as tested on the Air Force Laboratory rain erosion test apparatus operated and located at the Cornell Aeronautical Laboratory.

Early studies at the Cornell Laboratory showed that the paints and plastics evaluated had a very short life, generally in the range of one to two minutes at 500 miles per hour in rain. The effect of droplet size, velocity, and angle of impact on paints, metals and plastics was investigated.

As evidence of the increase of erosion with velocity, it was found that a specimen that underwent testing at 500 mph in a special rain cell showed effects of erosion in only one minute, while a similar specimen run at 200 mph required 24 hours of testing before erosion began to show.

The Air Force has reported that the severity of rain erosion has been indicated by the failure of antenna masts, radar housing, and similar non-structural components. Early recognition of the problem and methods that were developed to reduce the effect of erosion have helped maintain this safety record.

Materials Department personnel at Cornell Laboratory have, under the guidance of Dr. Philip K. Porter, experimented with nearly 3,000 materials of plastic and elastomeric nature.

For the investigation, a special cell was erected where simulated rainfall could be produced. A propeller-type blade, which would be rotated up to speeds of 760 miles per hour in the rain, was used to evaluate materials for rain erosion resistance. Specimens were mounted on the leading edge of the blades.

Slow motion pictures of specimens attached to the blade's leading edge moving at velocities of 500 mph showed that the raindrops,

upon impact, splattered into thousands of tiny particles, an effect, when multiplied by hundreds of raindrops, that caused pitting and wear.

Of the large number of materials evaluated, elastomeric or rubber coating systems were the most satisfactory. These materials were also evaluated for such properties as adhesion, outdoor durability, resistance to water and service fluids, and effects of temperatures from —65 degrees to 400 degrees.

Even though the Grumman Tiger was flown for the first time last summer, wind tunnel tests are still being continued by the Cornell Laboratory so that more accurate engineering data on the ship's performance can be acquired.

The Tiger was designed by Grumman around the Navy's concept of a powerful carrier striking force and can carry the most modern armament, including air-to-air and air-to-ground missiles.

More than 150 hours of test time have already been logged in the variable density wind tunnel and all of it is in the transonic speed range.

The Laboratory-developed a 3 x 4 foot transonic throat, which can be inserted in the 8½ x 12 foot tunnel test section, has been used for the testing. The throat is of the perforated wall type construction that minimizes the usual reflection of shock waves onto the model by the tunnel walls. The walls, being "porous-like," act to cancel out these reflected waves, which can interfere with the accurate collection of data on the model.

Cornell's wind tunnel is one of the busiest and most versatile in the nation, performing more than 3,000 hours of testing for the military services and aircraft industry during the last year. Nearly half of this testing was in the vital transonic speed range.

Industry Grants for Education

Cornell University is one of the 150 or so colleges of the country which will receive financial aid from the various industries of our Nation. Recognizing that the future of the nation may well be in the hands of such institutions of higher learning as Cornell University, U. S. industry has adopted a new attitude toward higher education. The recent announcement by General Motors that they have created a $2,000,000 a year gift program has highlighted the recent developments in the program. Other companies with the program they have, or will sponsor, follow:

Ford Motor Co. finances about 70 scholarships a year for the sons and daughters of employees and also gives $500 annually to each private college or university the students happen to choose.

The Gulf, Mobile & Ohio Railroad has given more than $185,000 since 1951 to private colleges along its route.

DuPont now pours $2,500 grants into the chemistry departments of 50 different campuses, and expects to give in various ways $800,000 this year.

The Radio Corp. of America will pay for 26 scholarships (at $800) this year.

Standard Oil Co. (*N. J.*) spread $450,000 over 138 campuses plus $50,000 for the National Fund for Medical Education last year.

Union Carbide's plan: $50,000 for 400 scholarships to more than 30 colleges.

Standard Oil Co. (Ind.) gave more than $350,000 in 1954, and matches its scholarships with equal gifts to each campus.

U. S. Steel last year gave $700,000 in unrestricted gifts.

Bethlehem Steel since 1953 has given $321,000 to the colleges—if privately endowed—of young employees completing its collegiate training program.

The Columbia Broadcasting System is giving $32,000 to the alma maters of its own selected executives.

General Electric has promised to match every employee's gift to his own college up to $1,000, and will spend "substantially more" than $1,000,000 in 1955.

Speaking Contest Winners

Thomas H. Arnott, a fifth-year student in mechanical engineering at Cornell, has won first prize of $25 in a public speaking contest held by the Cornell student branch of the American Society of Mechanical Engineers. His paper was on "Automobile Air Conditioning Control Systems."

Barry Kolton, also a fifth-year student in the school, won second prize of $15 for a paper on "The Flying Saucer Paradox." David Narins, a fourth-year student, won third prize of $10, discussing "The Use of Models in Modern Engineering Practice." The contest took place Thursday (March 17) at Cornell.

Mr. Arnott will represent Cornell in a similar contest during the ASME region three conference at Johns Hopkins from April 23-30, where he will compete with students from 18 other schools in New York, Maryland, Pennsylvania, Delaware and the District of Columbia. He is a son of Mrs. Pauline Pruden, 3 Harvey Court, Baldwin, N. Y., and a graduate of Hempstead High School.

Mr. Kolton is a son of Mr. and Mrs. Heyman Kolton, 477 Leslie Street, Newark, N. J., and a graduate of Weequahic High School.

Mr. Narins is a son of Mr. and Mrs. Samuel Narins, 22 Willow Road, Woodmere, N. Y., and a graduate of Woodmere High School.

AIEE Contest Winners

Three Cornell students—Leonard A. Mende, Edward F. Sutherland and Edmund G. Rynaski — have won prizes of $25, $15 and $10, respectively, for papers presented in a contest sponsored by the Ithaca section of the American Institute of Electrical Engineers.

All three are fifth-year students in the School of Electrical Engineering at Cornell, and Mr. Mende is double - registered in the Cornell Law School.

Prof. M. G. Malti of the school was in charge of the contest, the finals of which took place Friday (March 18) in Binghamton, N. Y.

Mr. Mende, son of Mr. and Mrs. William Mende of 523 Park Avenue, Albany, discussed "What Every Engineer Should Know About Patent Law." By placing first in

this contest, he is eligible to represent the section in a northeastern district contest to be held at Cornell on April 28.

The second prize went to Mr. Sutherland for his paper on "A Sound Track for the Home Movie Camera." He is a son of Mrs. C. W. Sutherland, 94 Otis St., Hingham, Mass.

Mr. Rynaski, son of Mrs. Frances Rynaski of 613 North Colony St., Meriden, Conn., discussed "A Servo-mechanism X-Y Recorder."

Cyclonite

(Continued from page 21)

cyclonite have important application in one of the most interesting developments in explosives to come out of the last war; the so-called "plastic explosives" or "explosive putties." These were soft, plastic, somewhat sticky mixtures of cyclonite and a binder, used in demolition operations. A gob of the stuff could be plastered on anything one wanted to cut or pierce, such as a bridge girder, tank, or pillbox, and the charge detonated. The ensuing very brisant explosion would shatter the object more effectively than other forms of demolition.

The earliest such mixture, known as "RDX Composition C," was essentially a mixture of 88 parts finely divided cyclonite and 12 parts lubricating oil. This was superceded by Composition C-2 and then Composition C-3. This last explosive is composed of 78 percent cyclonite and 22 percent resinous binder of nitrated aromatic hydrocarbons and nitrocellulose. The binder is also explosive, and C-3 has a better cutting action on steel plate than either Composition C or C-2. In the Joint Army-Navy specifications for Composition C-3, a one-inch cylinder of the explosive weighing 20 grams is required to perforate a ¼ inch mild steel plate placed flat against the end of the cylinder.

Future Use Of Cyclonite

By and large, because of its cost, cyclonite will remain a military explosive, although some blasting caps and "primacord" (explosive rope) for civilian use are now being loaded with it. And since the demand for widespread destruction in military operations is more efficiently met by nuclear devices, it is possible that the world may never again see cyclonite and similar explosives produced on as large a scale as in the Second World War.

Though hardly classifed as a "better thing for better living," the colorful history and unusual properties of this once strategic compound make it now one of the more interesting footnotes in organic chemistry.

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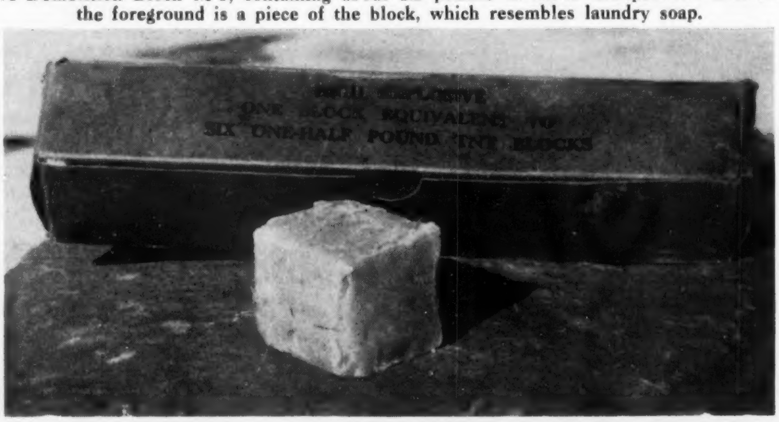
A Demolition Block M-3, containing about 2.2 pounds of RDX Composition C-3. In the foreground is a piece of the block, which resembles laundry soap.



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Steel

(Continued from page 16)

mixed with approximately six per cent minus one eighth inch carbon in the form of coke breeze or anthracite fines. A bed of mixture is fed onto a moving grate which has a suction applied beneath it, causing a downdraft through the charged mixture. The mixture is ignited on the top of the bed and the carbon burns progressively down through the bed, fusing metallic particles together into a porous open celled structure called sinter.

Pelletizing

Concentrates are fed into a horizontal revolving drum which rolls them up into balls approximately one half inch in diameter. These are then heated to a temperature below the actual fusing temperature but high enough to cause cementing to take place. There are two different methods being tried for this heating. One is the shaft furnace in which the pellets are fed in at the top, fired about one fourth of the distance down and then allowed to cool for the balance of their journey to the bottom of the furnace where they are withdrawn. In the second method the green pellets are charged onto a traveling grate similar to a sintering grate. In this process they are dryed, preheated, baked, and cooled in successive steps on the grate. The experiments on all of these processes are now being carried on in production size pilot plants. On one of these processes very likely hangs the future of the steel industry of the United States.

Lightning

(Continued from page 12)

feed enough charge to the leader to keep the electric field intensity at its tip greater than the air's breakdown voltage, it will continue to descend, and may or may not branch out. All the time it is leaving behind a conducting channel of ionized air which will provide a path for the return stroke.

As the leader nears the earth's surface it causes an increasing field intensity to appear there which may be sufficient to start lightning streamers upward perhaps to a height of fifty feet. This does not always happen, but it is likely to when tall trees or buildings are present to provide points where the earth's charge can concentrate. Although this condition is logically necessary, it did not hold in Fig. 3, demonstrating lightning's capricious nature.

The meeting of an upward streamer and a downward leader initiates the return stroke. It follows the ionized path of the leaders, extending down their branches as it comes to them, and continues to flow after contact with the cloud charge center until the charge is neutralized.

Charge Centers Cause Multiple Strokes

Mention was made earlier of the actual complexity of a cloud. This is important because it may result in multiple instead of single strokes. A multiple stroke is a series of discharges called components traveling in rapid succession down the same path, each discharging a different charge center. The presence of adjacent charge centers drives the process; when one is neutralized a streamer goes from it to another one, connecting the second center to the ionized channel which leads to the earth and starting a second stroke.

A component has a leader and a return part, but the leader differs from the pilot or stepped types in that its motion is continuous in previously ionized air—it is called a dart leader. Even if the path is blown aside by high winds the components follow it faithfully. As many as forty components have been recorded in one multiple stroke. An oscillogram of the current of one of these strokes would show a number of current peaks superimposed on a low "continuing current," which is often too small to be recorded (below 20 amp.—see Fig. 4). The time which elapses during all these processes is very small—a single stroke is about half a second. Peak currents of over 200,000 amperes have been known to flow, but the usual value is on the order of tens of thousands of amperes. The smaller values measured at the Empire State Building probably indicate the influence of the building's height.

"Hot," "Cold" Lightning Contrasted

Another aspect of lightning is its current wavefrom, two types being recognized on this basis. There are

(Continued on page 57)

Technibriefs

Every day could be wash day somewhere on the railroads if a revolutionary new theory recently conceived proves economically feasible:

The theory points to washing rails—with a detergent possibly—to help eliminate one of the railroads' oldest and most expensive problems—slipping of locomotive wheels.

The new theory holds that slipping is caused by an extremely thin, practically invisible layer of oil approximately one molecule thick, which spreads itself over the running band of a rail at the onset of rain or when there is dew. Despite its thinness, this "monomolecular layer" can withstand pressures so high (up to 75,000 pounds per square inch) that locomotive wheel loads ordinarily used will not break through it.

At many places on railroad track, accumulations of journal oil can be observed outside the wear band. When the rails become moist or damp, the oil spreads over the rail, pushing the water off. The result is a thin film of oil which causes slipping, and often stalls crack trains traveling on grades.

Journal oil, used in the bearings of freight cars, contains some percentage of animal oils which spread rapidly over a polished surface in the presence of a small amount of water. Oxidized mineral oils seem to exhibit the same characteristics as animal oils or fish oils and spread over a polished surface in the presence of moisture.

One drop of oil in the presence of moisture has the ability to cover a surface of five square meters. If tracks were not interrupted by rail joints, this one drop would spread along the polished running part of the rail (5/8 inch wide) to form a slippery film for a distance of two miles.

It is felt that if the source from which the film spreads is removed, the presence of moisture will no longer cause slipping.

Cleaning methods now under investigation, in addition to water, include detergents, solvents, open flame, and ultraviolet light. If a suitable cleansing agent is found, much of the sand currently used on locomotives to improve traction on wet days can be eliminated, with the added benefit of a reduction in the drag of the train.

Color TV Tube.

Photographic Method Forms Color TV Screen

In a color television picture tube screen, three different phosphor materials may be placed in an interspersed dot pattern on a glass plate, a phosphor for each of three primary colors, red, blue, and green. An engineer at Sylvania Research Laboratories uses a photographic method of forming the complex screen. Light from the point source zirconium lamp passes through an aperture plate containing more than 200,000 precisely spaced small holes. Rays of light fall in the desired dot pattern on a photographic emulsion containing the color phosphor. After controlled exposure and processing, only the phosphor remains in the pattern. The process is repeated for the other two phosphors with the screen and aperture plate moved slightly to permit the new dots to fall between those previously formed. A full color picture is produced by each of three electron streams being made to fall on the appropriate set of color phosphor dots.

Automatic Production Of Electronic Circuits

An automatic system to place components in varied types of electronic equipment sub - assemblies will be a step toward the automatic factory. The system, with flexibility to switch rapidly from one type of assembly operation to another, is being built by General Electric for the Army Signal Corps as an industrial preparedness measure.

Unlike automatic assembly systems for long-run, standardized operations, the new system can adapt itself immediately to work on varied sizes of circuit boards, using different types and sizes of components with up to eight leads each.

The significance of such a flexible system is said to stem from the fact that the majority of electronic equipment business, dollarwise for both commercial and military use, is measured in the thousands of units rather than in the tens of thousands for such entertainment equipments as home radios and TV sets.

The new system has an electronic reader, which sets up production steps from punch cards. When a different job is to be done, the reader is fed the punch card for the job. It then sets up the system to prepare and test components, convey them to the assembly unit, assemble them, and test the completed sub-assembly.

The system can be programmed to place any number of components, limited only by the size of the circuit boards and the size of components themselves, and will be capable of placing as many as 1,600 components per hour. All the placement operations are done by one placement unit; in contrast, the mass-production type assembly systems place one component at each unit, and require as many placement units as there are components to be placed. Attendants are needed only to load circuit boards and components, and to check operation of the system at a central control console. This new step towards automatic production follows the automatic punch press announced last January, which was similarly controlled by a punch card "reader" and featured a similar degree of flexibility.

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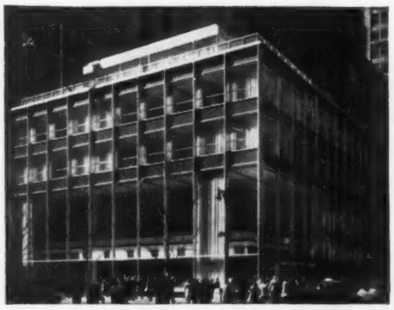

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Lightning

(Continued from page 52)

hot lightning, which has a low current and long duration, and cold lightning which is known by a high peak of very short duration.

The terms "hot" and "cold" are derived from the physical damage each type causes. Hot lightning will start a fire, but it will not produce the shattering effect of cold, and vice versa. The difference is due to the failure to reach the ignition temperature of inflammable materials in the short time period of cold lightning. But the cold strokes will, however, perform such stunts as vaporizing a copper wire, making it vanish, without harming the insulation which surrounded it. An interesting historical note was provided by Pliny the Elder, a Roman author, who included the following passage in his *A Natural History* in the first century A.D.:

> "Of thunderbolts themselves several variations are reported. Those that come with a dry flash do not cause fire but an explosion. The smoky ones do not burn but blacken. There is a third sort called 'bright thunderbolts' of an extremely remarkable nature; this kind draws casks dry without damaging their lids and without leaving any trace and melts gold and silver in their bags without singeing the bags themselves at all and without melting the wax seal. Marcia, a lady of high station in Rome, was struck by lightning while with child and tho the child was killed, she herself survived without being otherwise injured. Among the portents in connection with Catiline, a town councilor of Pompeii named Marcus Herrenius was struck by lightning on a fine day."

Protection Methods Are Effective

Present lightning protection practices are quite effective due to a knowledge of the mechanism of the stroke. Electric power system protection is a broad subject which includes the use of electronic as well as electro-mechanical devices, but since this paper is mainly concerned with the stroke itself only that device will be discussed which depends directly on an understanding of the stroke. It is a form of Franklin's invention, the lightning rod.

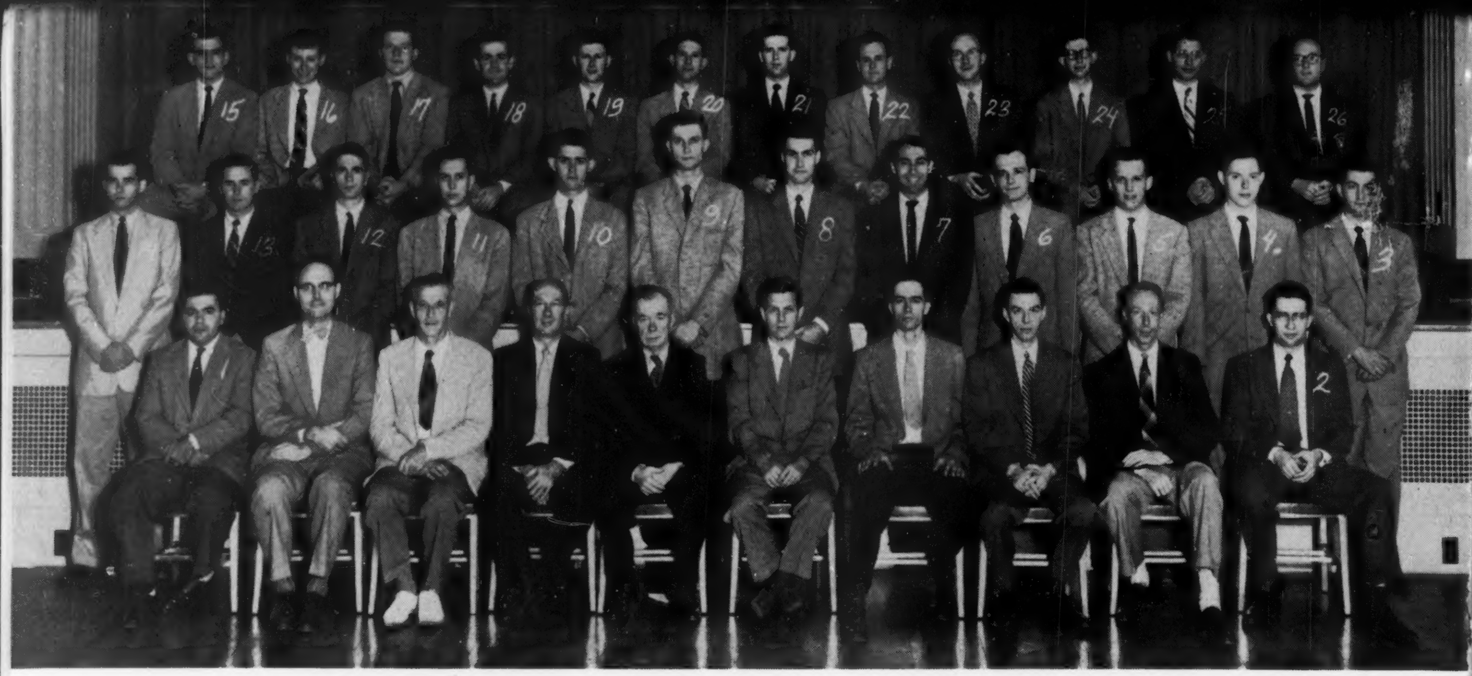
The principle of operation of the lightning rod is that streamers start up from certain points on the earth when it is approached by the downward leader, and start the stroke by contacting the leader. It is apparent that the first streamer to do this will be one from a high object, and the function of the lightning rod is to be that object. For a grounded, vertical mast there is an area known as the "cone of protection" which has its apex at the mast's tip and its circular base on the earth's surface around the mast. The diameter of the cone is roughly equal to the height of the mast; and the area enclosed by the base of the cone will have approximately 0.1% protection, meaning that 99.9% of the strokes to that area will either strike the mast or a point outside the cone of protection.

But in order to be effective, the lightning rod must be very well grounded; that is, the contact resistance between the rod and ground must be very small. If it is not, the large lightning currents flowing in the resistance will produce a huge voltage drop across it and the rod will then be at a high potential with respect to ground. When this happens, the stroke, after striking the mast, is likely to jump to some other, easier path to ground and do a great deal of damage on the way. For this reason it is dangerous for a human to stand under a tree during a thunderstorm; the tree is a high resistance and a stroke trying to find ground may strike an upper branch and then jump to the ground through the person.

Ground Wires Protect Power Systems

The application of these principles to electric power systems is through ground wires—conductors which run parallel to and above the transmission lines, and electrically connected to their supporting towers. When the towers are well grounded, the ground wires provide a protective "tent" over the lines similar to the cone of protection of the single mast. The number of direct strokes to lines has been greatly reduced by this practice; before its introduction strokes fell on unshielded lines at an average rate of once per mile per year in regions where the frequency of

(Continued on page 60)



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Not pictured: Lieb, D. P.

Lightning

(Continued from page 57)

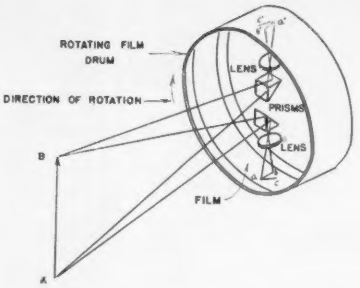
thunderstorms is not high.

To counterbalance their advantages, ground wires are expensive and the towers must be of heavy construction in order to support them. In locations where the frequency of storms or some other factor does not justify their use, protection is employed which acts after a stroke has struck the line and prevents power interruptions. Two such devices are lightning arrestors and expulsion tubes which allow grounding of the high currents but do not allow them to be followed by the normal line current. Another method is the use of a ground-fault neutralizer or Petersen coil which limits the value of fault current. A fourth protective technique is automatic reclosing; circuit breakers are used to disconnect the section of line where the fault occurs and immediately reconnect it, the process being re peated if the fault has not been cleared upon reclosing. In nearly all cases these measures allow a barely perceptible interruption of power.

Further Research Necessary

There are gaps in the knowledge of the habits of lightning which, if filled, would enable man to make it somewhat less a nuisance. One interesting problem is the effect of the earth on the location of the point of contact of lightning with ground and on whether the lightning will be hot or cold. The earth's influence is felt here in two ways—first is the effect of its resistivity on type and location, and second is the influence of physical features on meteorological factors relating to thunderstorms. Understanding of these might well make it possible to locate transmission lines so as to minimize the probability of a stroke.

Protection of individuals from lightning strokes probably interests everyone, and should be mentioned here before closing. The problem sounds simple — one must either stay out of the path of a stroke, or keep all parts of his body at the same potential. A good way to avoid a stroke in the home is to stay away from grounded or even large ungrounded metal objects, and refrain from handling electrical appliances. The statement has been



Schematic diagram of a High Speed Boys Camera.

made that a stroke will seek the easiest path to ground, and this is through a metallic condctor; hence the emphasis on the foregoing precaution. The safest location is inside a metal enclosure, grounded or not, such as a steel automobile—here is a case where the popular rumor is true.

The outdoors in general should be avoided during a storm. This is not because the walls of a house will in the least impede a lightning bolt, but standing near a point on the ground where a stroke falls may be fatal. When lightning enters the earth, large potentials and potential gradients appear in the earth's surface around the spot. Animals face greater danger from this cause; a voltage may appear between their fore and hind legs which is large enough to kill them.

There is really not much reason to restrict one's activities during a thunderstorm—a person's chance of being struck is on the average about one in 350,000. But, as McEachron points out, we are dealing with a possibility and not a probability. As for unpredictability, it has been shown that research has partially removed lightning from that realm and made use of new knowledge for the protection of life and property.

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